Astronomy®

THE WORLD'S BEST-SELLING ASTRONOMY MAGAZINE /// APRIL 2025

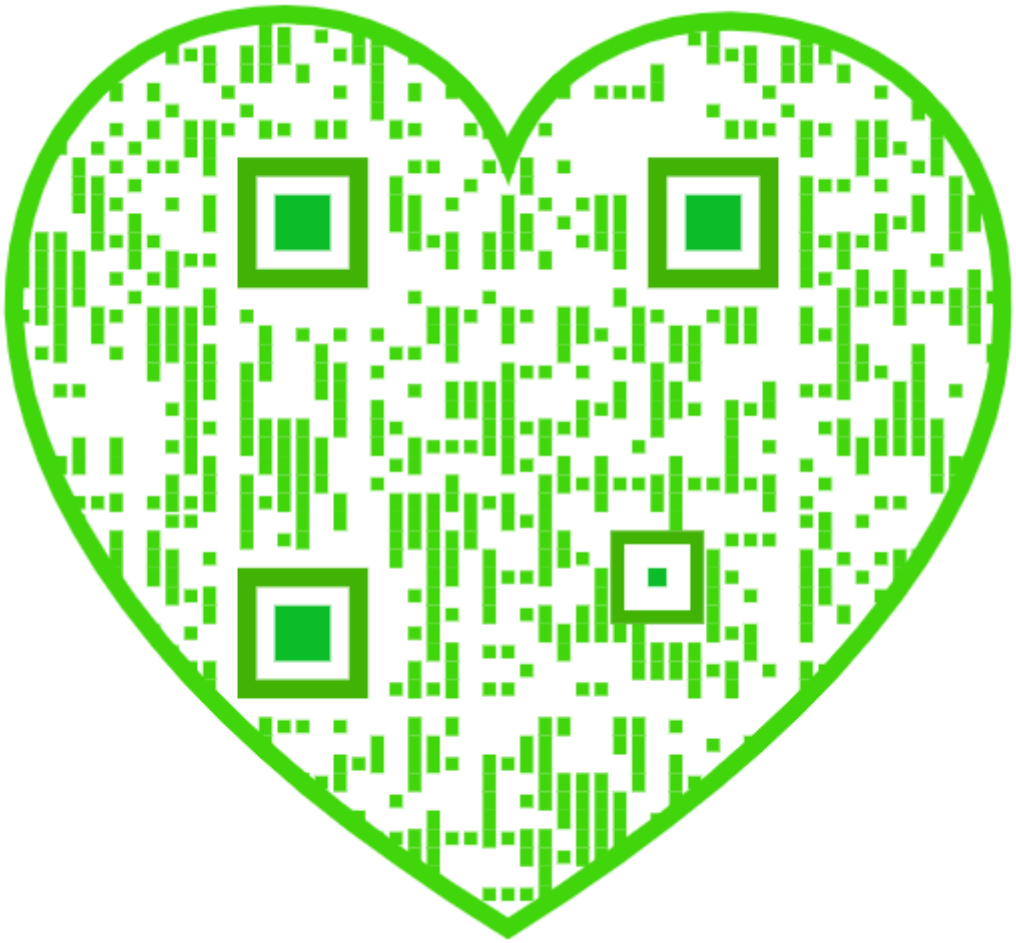
SPECIAL ISSUE

EARTH AS A PLANET

WHERE WE ARE, WHERE WE'VE BEEN,
AND WHERE WE GO FROM HERE

BONUS ONLINE CONTENT CODE p. 3

Vol. 53 • Issue 4



NEW SECRETS OF ANCIENT EGYPT – GROUNDBREAKING DISCOVERIES

A ROYAL EVENING WITH DR. ZAHI HAWASS

EVENT of the YEAR!

THE WORLD'S MOST FAMOUS ARCHAEOLOGIST

USA & CANADA GRAND LECTURE TOUR

MAY – AUGUST 2025

THE LOST PYRAMID • MISSING ROYAL TOMBS • NEW FINDS AT THE VALLEY OF THE KINGS • PROGRESS IN THE GOLDEN CITY

THE SEARCH FOR CLEOPATRA'S TOMB • SECRET ROOMS IN THE GREAT PYRAMID • KING TUT'S UNTOLD SECRETS • & MORE REVELATIONS!

Discover the greatest secrets of the Land of the Pharaohs! The time has come for the legendary Dr. Zahi Hawass to unveil ancient Egyptian mysteries that were lost for millennia.

The real-life Indiana Jones returns to North America to share the latest discoveries, reveal groundbreaking finds drawn from his most recent excavations and make the most thrilling announcements of his remarkable career. **This event will make history – live on stage – and you won't want to miss it!**

Join Dr. Hawass for a captivating all-new multimedia presentation prepared exclusively for this historic tour. Stay after the lecture for a Q&A session and a book signing.

May 1	Phoenix, AZ
May 3	Los Angeles, CA
May 6	San Diego, CA
May 9	Las Vegas, NV
May 11	Oakland, CA
May 14	Portland, OR
May 18	Seattle, WA
May 22	Denver, CO
May 25	Austin, TX
May 27	Oklahoma City, OK
May 29	Dallas, TX
June 1	New Orleans, LA
June 5	Tampa, FL
June 7	Orlando, FL
June 11	Nashville, TN
June 14	Atlanta, GA
June 16	St. Louis, MO
June 18	Charlotte, NC
June 21	Pittsburgh, PA
June 25	Columbus, OH
June 28	Chicago, IL
June 30	Minneapolis, MN
July 3	Cleveland, OH
July 6	Indianapolis, IN
July 9	Boston, MA
July 12	Baltimore, MD
July 16	Virginia Beach, VA
July 19	New York, NY
July 21	Philadelphia, PA
July 23	Washington, DC
July 26	Vancouver, BC – Canada
July 30	Toronto, ON – Canada
August 2	Montreal, QC – Canada

Seats are limited – Register now

www.ZahiLectures.com

contact@zahilectures.com

646-757-1717

Online Content Code: ASY2504
Enter this code at **www.astronomy.com/code** to gain access to web-exclusive content.

CONTENTS

APRIL 2025
VOL. 53, NO. 4

ON THE COVER
Earth is approaching a critical moment in the future habitability of the planet. NASA IMAGES BY RETO STÖCKLI, BASED ON DATA FROM NASA AND NOAA

FEATURES

12 COVER STORY
Solving the climate equation
Most people worry about climate change, but few know what to do. The right tools allow us to convert scientific urgency into effective action.
KATHARINE HAYHOE

20
How to build climate solutions
Tony Fadell invented the iPod, co-invented the iPhone, and co-founded Nest. His follow-up? Turning down the heat for the entire planet.
MARK ZASTROW

28
Sky This Month
Lyrid meteors dazzle.
MARTIN RATCLIFFE AND ALISTER LING

30
Star Dome and Paths of the Planets
RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY

36
Don't mess with Antarctica
Once thought a block of worthless ice, this continent plays a key role in stabilizing Earth's climate.
CHRIS RAPLEY

44
Studying ourselves
Here's a sampling of some of the satellites that take a look at our planet. **KOREY HAYNES**

48
A telescope for your smartphone
Vaonis' compact, easy-to-use Hestia will turbocharge your phone for astroimaging.
RAYMOND SHUBINSKI

54
Ask Astro
A lost planet?

COLUMNS

Secret Sky 50
STEPHEN JAMES O'MEARA

Observing Basics 52
MOLLY WAKELING

IN EVERY ISSUE

From the Editor 4
Astro Letters 5
New Products 53
Advertiser Index 53
Reader Gallery 56
Breakthrough 58

7 QUANTUM GRAVITY
Everything you need to know about the universe this month: NEOWISE's final image released, NASA probe makes a close pass to the Sun, and more.

ONLINE FAVORITES

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.

The Space Store
Perfect gifts for your favorite science geeks.

News
The latest updates from the science and the hobby.

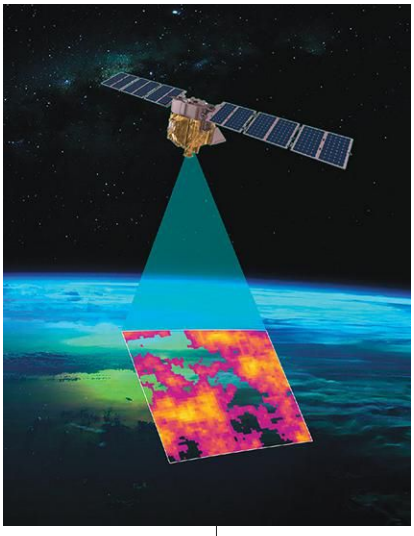
Community Forum
Enthusiasts connect and share.

Picture of the Day
Gorgeous photos from our readers.

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Firecrown Media Inc., Firecrown Media Inc., 405 Cherry Street, Chattanooga, TN 37402. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, PO Box 850, Lincolnshire, IL 60069. Canada Publication Mail Agreement #40010760.

ONLINE FAVORITES, LEFT TO RIGHT: ASTRONOMY.COM; NASA/JPL/SPACE SCIENCE INSTITUTE; CHINGYUNSONG/DREAMSTIME.COM; N.A.SHARP/NOIRLAB/NSF/AURA

Earth as a habitat



MethaneSAT is one of many Earth satellites informing us that the planet is in rapid climate change.
METHANESAT

Welcome to a special issue of *Astronomy* devoted to Planet Earth. As the extraordinary pace of astronomical discovery carries on, we increasingly see that the stuff of life is spread throughout the cosmos. We know of several hundred billion stars in our galaxy, at least 100 billion galaxies, and planets around most of the stars we see.

And despite the drumbeat of evidence, we still know of just one planet in the cosmos with life — the one you're standing on. Most of us think of life as precious, and it's certainly fragile. We live in a carefully balanced ecosystem that is rapidly changing, a change that began with the Industrial Revolution a couple of centuries ago.

It's funny that astronomy enthusiasts, by nature, are focused on science, and most of them believe in science. But you cannot believe in science only when it agrees with your assumptions and long-held beliefs. That's the whole point of science: It's a systematic way of understanding reality, and you either believe in it all the time, where the evidence leads, or you don't. You can't believe in science only when it agrees with your preconceived notions.

Science tells us that climate change is real and is changing the planet — and more to the point, its potential habitability — at breakneck speed. Remember the words of comedian George Carlin: "The planet has been through a lot worse than us … earthquakes, volcanoes, plate tectonics, continental drifts, solar flares, sunspots, magnetic storms, the magnetic reversal of the poles, hundreds of thousands of years of bombardment by comets and asteroids and meteors, worldwide floods, tidal waves, worldwide fires, erosion, cosmic rays, recurring ice ages. … The planet isn't going anywhere — we are. … The planet will shake us off like a bad case of fleas, a surface nuisance."

Begin by reading leading climate scientist Katherine Hayhoe's story in this issue. Then think about what we can do so that Earth is a nice place to live not just now, but also a million generations from now. Don't we bear some responsibility for others to come, and not simply the current moment?

Yours truly,

David J. Eicher
Editor

Follow Dave on
Facebook:
facebook.com/davidjohneicher
X (formerly Twitter):
@deicherstar
Instagram:
eicher.david

FOLLOW *ASTRONOMY*

facebook.com/AstronomyMagazine
twitter.com/AstronomyMag
youtube.com/user/AstronomyMagazine
instagram.com/astronomy.magazine

Astronomy

Editor-in-Chief David J. Eicher
Assistant Design Director Kelly Katlaps

EDITORIAL
Senior Production Editor Elisa R. Neckar
Senior Editors Alison Klesman, Mark Zastrow
Associate Editors Michael E. Bakich, Daniela Mata
Editorial Assistant Samantha Hill

ART
Illustrator Roen Kelly
Production Director Kelly Kramer Weekley
Operations Specialist Melissa Valuch
Production Specialist Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Adam Block, Martin George, Tony Hallas, Phil Harrington, Alister Ling, Stephen James O'Meara, Martin Ratcliffe, Raymond Shubinski, Richard Talcott, Molly Wakeling

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Jim Bell, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

Firecrown
Chief Executive Officer Craig Fuller
President David Bradford
Chief Strategy Officer Keith Beckman
Chief Commercial Officer Preston Brown
Chief Operations Officer Nicole McGuire
Chief Financial Officer Lan Phan
Vice President, Finance/Controller Amanda Joyce
Vice President, Creative Barry Carpenter
Group President, Hobby Division David Carr
Group President, Aviation Division Lisa DeFrees
Group President, Marine Division Glenn Sandridge
Editorial Director Meg Scarbrough
Vice President, General Counsel Darren Caputo
Human Resources Director Suzie Matoh

ADVERTISING DEPARTMENT
Advertising Representative Kristi Rummel
Phone (608) 435-6220
Email kristi.rummel@firecrown.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Email terri.meunier@firecrown.com

CUSTOMER SALES AND SERVICE
Phone (877) 246-4835
Outside U.S. and Canada (847) 313-3921
Customer Service AstronomyMagazine@Omeda.com

CONTACT US
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com

For reprints, licensing, and permissions:
PARS International at www.parsintl.com

Copyright © 2025 Firecrown Media Inc., all rights reserved. This publication may not be reproduced in any form without permission. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Single copy: $6.99 (U.S.). Print + digital subscription rate: U.S.: 1 year $58.95. Canadian: Add $12.00 postage. Canadian price includes GST, payable in U.S. funds. All other international: Add $22.00 postage, payable in U.S. funds, drawn on a U.S. bank. BN 12271 3209 RT. Not responsible for unsolicited materials.

FIRECROWN

Like most galaxies, NGC 5643 is moving away from our own — a characteristic discovered by Slipher and Hubble. ESA/HUBBLE & NASA, A. RIESS ET AL. ACKNOWLEDGEMENT: MAHDI ZAMANI

We welcome your comments via email to **letters@astronomy.com**. *Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Slipher's legacy

I thoroughly enjoyed reading "Renaming the Hubble constant" in the December 2024 issue. Would I favor "giving credit where credit is due" as a response? Not in this case. Allow me to explain. Dr. Slipher came to his conclusions over a hundred years ago, and obviously he has been deceased for some time. Science is at fault in this matter and cannot correct it. Dr. Slipher is not alive to celebrate this news. In short, it is too little, too late. **—Glenn Siciliano,** McDonough, GA

Giving credit

Having read the article by Douglas MacDougal, Joseph Marcus, and Marcia Bartusiak, I am convinced that V.M. Slipher has not been properly acknowledged for his contributions. I would support his name being included in the naming of the distance and recession speed relationship. In short, I would be willing to join in signing a consensus petition for presentation to the IAU including the appropriate acknowledgments for the name of the relationship. **—Kevin M. Stewart,** Lancaster, PA

Make your own rainbow

Thanks for Raymond Shubinski's story on rainbows in the November 2024 issue! I only wish he had included directions on how to produce your own on demand. I have done this many times to engage our children and even adults to get them interested in such things. On a sunny day, with the Sun at roughly the angle Ray mentions, stand with your back to the Sun with a garden hose in hand. Turn the sprinkler head to mist and point the hose in front of you, running the hose up and down until the rainbow appears. Participants should have their eyes at the same level. There's your self-made rainbow! Kids are usually amazed, as are most adults. **—Phil Schenkenberg,** St. Louis, MO

Errata: *The December article "Mars may host oceans' worth of buried water" incorrectly stated the Scripps Institution of Oceanography is managed by the University of San Diego. It is actually managed by the University of California, San Diego.*

QHYCCD
miniCAM8
VdB 62 Nebula captured with QHY miniCAM8M courtesy Abdullah Al-Harbi
QHYCCD's New miniCAM8
Compact: Only 4.1" x 2.6"
8.4 MP Sony IMX585 Mono CMOS
Cooling to -45C, High QE, Low Noise
Internal 8-Position Filter Wheel
LRGB + Narrowband Filters + Dark Filter
Mono sensor $799 - Color sensor $699
See it at NEAF / NEAIC / April 4-7
www.QHYCCD.com

NEAF

April 5-6, 2025

www.rocklandastronomy.com/neaf.html

Northeast Astronomy Forum

The World's Largest Astronomy & Space Expo

TAKE THIS AS YOUR GUIDE TO THE SHOW AND VISIT THESE LEADING VENDORS
Also see more information online at **www.astronomy.com/neaf**

10MICRON

10Micron offers premium Italian quality and technology for top level astro imaging and research, along with the best customer service, thanks to our experienced US and Canadian dealers; visit us at NEAF/NEAIC to discover our mounts.

+39 02 96457330
info@10micron.com
www.10micron.com

AstroWorld

Celebrate AstroWorld Telescopes' 2nd Anniversary!

From budding stargazers to pro astrophotographers, our outstanding customer support has you covered. Thanks for your incredible support—keep imaging, Keep Educating and Clear Skies!

516-273-3771
www.astroworldtelescopes.com
info@astroworldtelescopes.com

Celestron

Join Celestron at NEAF 2025 for a thrilling glimpse of tomorrow. Explore the groundbreaking Origin Intelligent Home Observatory and be first to see NEW astronomy innovations—plus, enter our giveaway!

310-328-9560
www.celestron.com

Meteorite Jewelry Store

Featuring astronomically themed fine meteorite jewelry done in gold, platinum and gemstones.

Rings, pendants, accessories, and even flying saucers! Home of the 9 Planets ring since 2007.

831.336.1020
Meteorite Jewelry Store
http://meteoritejewelrystore.com

Oberwerk

High-Performance binoculars for earth & sky. Serving the amateur astronomy community for 25 years. See all seven XL Series binocular telescope models at NEAF 2025.

937-640-1040
sales@oberwerk.com
https://www.oberwerk.com

OCULUM

The world's best deep sky atlases and guides, breathtaking coffee table books, innovative lunar atlases: Germany-based Oculum publishers will showcase unique printed publications for amateur astronomers at NEAF 2025.

info@oculum.de
www.oculum.de

Photonic Cleaning Technologies

Cleaning your optics? First Contact Polymer is as simple as Apply. Dry. Peel! A unique, touch-free process that won't scratch your optics. Order with coupon CLEARSKY25 for a 15% discount

+1-608-467-5396
Sales@PhotonicCleaning.com
www.photoniccleaning.com

QHYCCD

Come see the remarkable IMX585M based miniCAM8M at NEAF/NEAIC. Compact and inexpensive yet powerful with a full complement of LRGB and Narrowband filters all for only $799!

btt@qhyccd.com
www.QHYCCD.com

Sky-Watcher

As we begin our next quarter-century, Sky-Watcher's singular passion has been to provide our customers with finely crafted astronomical instruments at accessible prices.

310-803-5953
support@skywatcherusa.com
www.skywatcherusa.com

Software Bisque, Inc.

Paramounts deliver all-sky pointing accuracy of 30 arc-seconds RMS and exceptional software that enables up to 20-minute unguided exposures. See our newest GEMs at NEAF!

303-278-4478
FrontDesk@Bisque.com
Bisque.com

STARPX

Enjoy astrophotography by automating image processing, making it accessible to all. Cutting-edge features: instant plate-solving, star-removal, and annotation.

778-991-5517
christian@starpx.com
https://starpx.com

ZWO

ZWO, the world-leading astronomy equipment manufacturer, aims to make astrophotography easy and fun. Explore the universe effortlessly with our innovative, user-friendly solutions!

+86 0512-65923102
info@zwoptical.com

SNAPSHOT

A PARTING GLANCE

A now-retired mission's final data release contains many treasures.

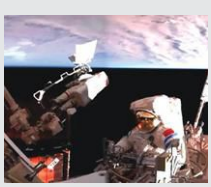
Despite completing its mission and burning up in the atmosphere last November, NASA's Near-Earth Object Wide-Field Infrared Survey Explorer (or NEOWISE) still has a lot to offer. Its final data release totaled more than 26 million infrared images, including this vista of the California Nebula (NGC 1499). Stars, colored blue and cyan, dominate at wavelengths of 3.4 and 4.6 micrometers. The light at 12 micrometers comes from dust, colored green, while red depicts warm gas glowing at 22 micrometers.

Located in the constellation Perseus, the California Nebula spans 100 light-years. The nebula itself appears bright green with a mix of orange, while the red at center is gas near the young, hot star Menkib (Xi [ξ] Persei). This star puts out 300,000 times more energy than our Sun. Its fast-moving stellar winds create a bow shock as they crash into interstellar material, creating the pileup of heated gas seen left of the star.

—SAMANTHA HILL

NASA/IPL-CALTECH/IPAC. BOTTOM FROM LEFT: CHINA MANNED SPACE AGENCY; NASA, ESA, CSA, STSCI, CHRIS WILLOTT (NRC-CANADA), LAMIYA MOWLA (WELLESLEY COLLEGE), KARTHEIK IYER (COLUMBIA); NASA/APL

HOT BYTES



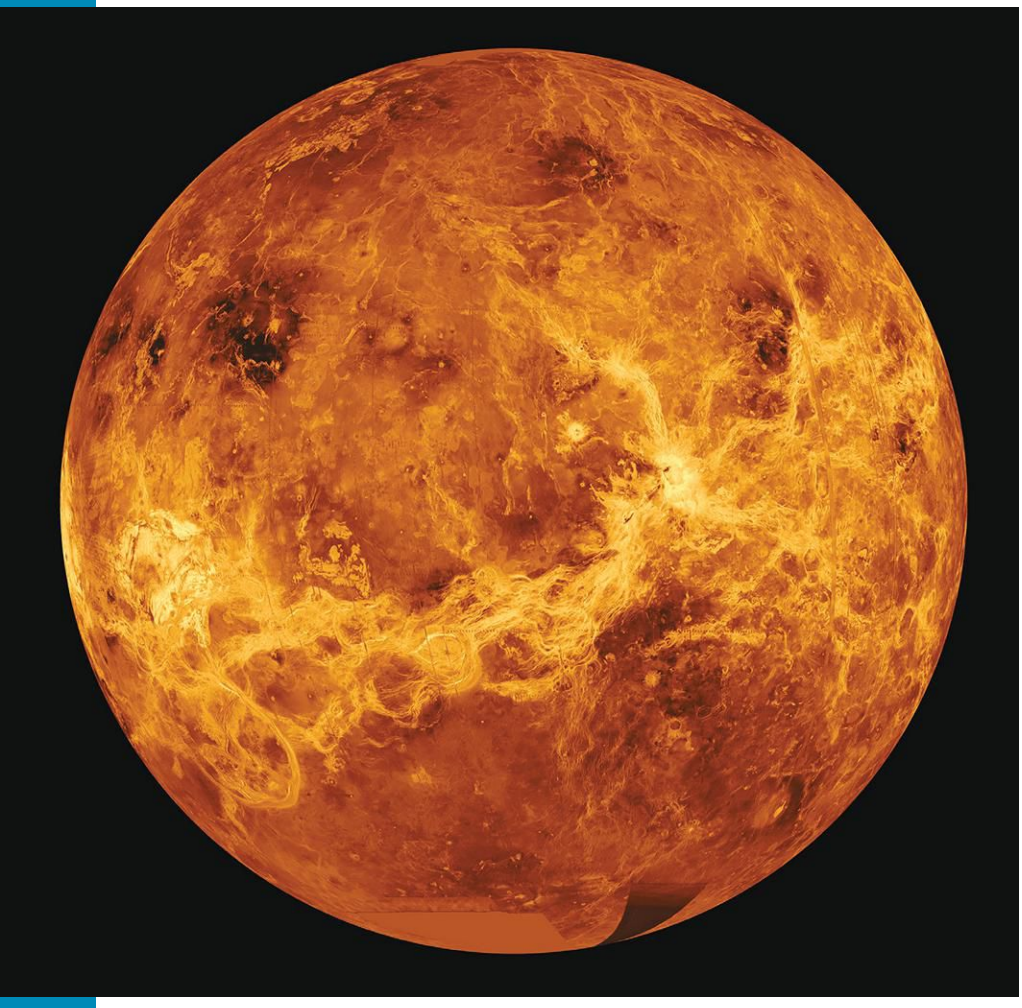
LONG WALK
Chinese astronauts Cai Xuzhe and Song Lingdong, of the three-person Shenzhou 19 mission to the Tiangong space station, completed a world-record-breaking spacewalk lasting 9 hours 6 minutes on Dec. 16/17.

FIREFLY GLOW
The Firefly Sparkle Galaxy appears as a long, curved streak due to gravitational lensing. Data from JWST show it is the earliest known Milky Way-sized galaxy that is still forming, 600 million years after the Big Bang.

SKIMMING BY
On Dec. 24, the Parker Solar Probe made its closest pass of the Sun yet, flying by at a distance of 3.8 million miles (6.1 million km) and reaching speeds up to 430,000 mph (692,000 km/h).

WAS VENUS ALWAYS TOO HOT FOR WATER?

A trio of researchers has suggested that Venus may never have had oceans to lose.



PERMANENT HEAT WAVE. This map of Venus' desolate surface has been stitched together using radar mosaics from the NASA Magellan mission, which circled the world from 1990 to 1994. New research suggests the world may always have been too hot to host liquid water. NASA/JPL

A new paper offers a scenario for the early solar system that could drastically revise our understanding of Venus' climate history and significantly alter the chance that it was ever habitable.

Research published Dec. 2 in *Nature Astronomy* suggests that contrary to the current idea that Venus once hosted surface water that has long since dried up, the planet has always been too hot to support oceans. Instead of a second Earth, early Venus was a steam world, which could support water vapor but whose surface temperatures — reaching as high as 1,340 degrees Fahrenheit (727 degrees Celsius) — never allowed oceans to condense.

"Over billions of years, this atmospheric steam would undergo photodissociation, breaking water molecules into hydrogen and oxygen, with the lighter hydrogen gradually escaping into space," says Tereza Constantinou, a Ph.D. student at the University of Cambridge, U.K., and first author of the paper. "This process ultimately left Venus with the arid atmosphere we observe today."

QUESTIONING HABITABILITY

Every star has a habitable zone: a region where a planet with an atmosphere could host temperatures — and thus potentially oceans — like Earth's. Our Sun's habitable zone is often considered to include Venus within its inner edge and Mars inside its outer bound, as both are thought to have once had oceans.

By challenging that idea for Venus, this work has implications for other star systems as well. "Knowing that Venus was likely never habitable, the Venus-like exoplanets that JWST [the James Webb Space Telescope] is characterizing are unlikely candidates for habitable conditions," Constantinou says. "This narrows the search for habitable and inhabited conditions on exoplanets, directing attention to Earth analogues."

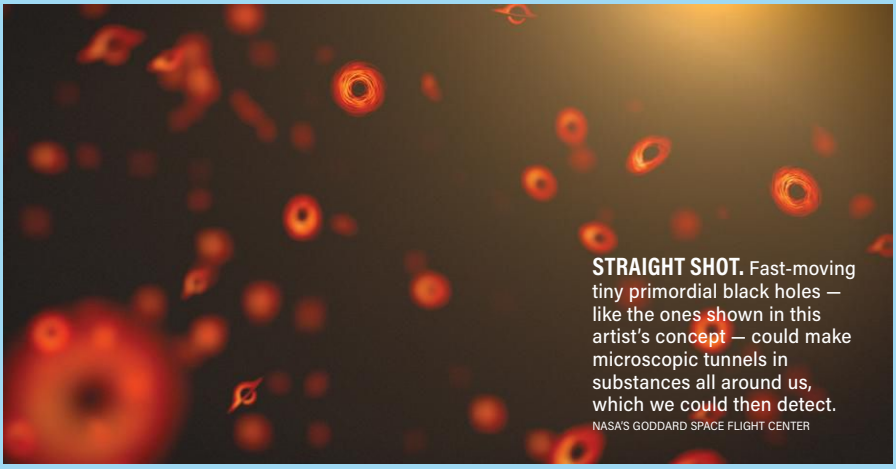
Future space missions could answer questions around Venus' climate history and confirm the team's findings. The European Space Agency's EnVision, expected to launch in the early 2030s, will investigate Venus from orbit, examining how the planet's atmosphere, surface, and interior interact. It will also search for evidence of past water.

NASA's DAVINCI mission has a similar timeline to EnVision. Its atmospheric probe will be able to learn more about Venus' atmosphere as it descends; that data will "speak to whether Venus was ever wet or habitable," Constantinou says.

Even a dry Venus still might host life — we'd just need to look higher. Conditions in the upper atmosphere are more temperate and Earth-like, and under certain scenarios could have fostered life.

In 2020, a team of researchers claimed to have found evidence of a gas called phosphine in the atmosphere of Venus. On Earth, phosphine is made by life and not much else, so it could be a potential indication of microbial life in Venus' atmosphere. The claim remains heavily disputed, but, if confirmed by future missions, would also rewrite the book on habitability.

"Any potential life in the venusian atmosphere would have originated and evolved under entirely different conditions, perhaps adapted to survive in sulfuric acid clouds — so, very much life as we do not yet know it," Constantinou says. — JOHN WENZ



STRAIGHT SHOT. Fast-moving tiny primordial black holes — like the ones shown in this artist's concept — could make microscopic tunnels in substances all around us, which we could then detect. NASA'S GODDARD SPACE FLIGHT CENTER

Want to find a black hole? Pick up a rock

PRIMORDIAL BLACK HOLES are tiny objects that astronomers theorize could have formed in the first second after the Big Bang. Although we've never seen any, finding one would both boost our understanding of black holes and offer a possible explanation for dark matter, the unknown substance that makes up roughly 85 percent of the universe's matter.

In a paper published Sept. 20 in the journal *Physics of the Dark Universe*, De-Chang Dai from National Dong Hwa University in Taiwan and Dejan Stojkovic from the University at Buffalo in New York discuss one unique way to potentially find primordial black holes. They say quickly moving primordial black holes might leave tiny holes in regular matter as they tunnel through, consuming all the material that falls into their itty-bitty event horizons.

Specifically, a black hole with a mass of 2.2×10^{19} pounds (10^{22} grams) would leave a hole 0.1 micrometer in size in rock, large enough to be seen with a regular optical microscope. The chances of this happening in any given space are astronomically small — but over cosmic timescales, not impossible. So, the authors suggest in their paper looking in "very old rocks, or even glass or other solid structures in very old buildings."

"We have to think outside of the box," Stojkovic said in a statement, "because what has been done to find primordial black holes previously hasn't worked."

The odds, they stress, are not good: The chance of a boulder even 1 billion years old having encountered a black hole is just 0.0001 percent. But if people across the world could look for black holes with little to no specialized equipment, it could be a chance to spy something incredible.

"You have to look at the cost versus the benefit. Does it cost much to do this? No, it doesn't," said Stojkovic. — KOREY HAYNES

QUICK TAKES

A GATHERING STORM

Stars like the Sun produce powerful superflares roughly every 100 years, according to an analysis of 56,000 stars observed by NASA's now-retired Kepler Space Telescope. If the Sun is similar, it may be overdue for such a flare, which would be more powerful than any on record.

SHORT-LIVED DUO

Astronomers announced Dec. 17 the first detection of a binary star system near the Milky Way's central supermassive black hole. Due to the black hole's gravity, this system will likely merge within a million years.

ACCIDENT REPORT

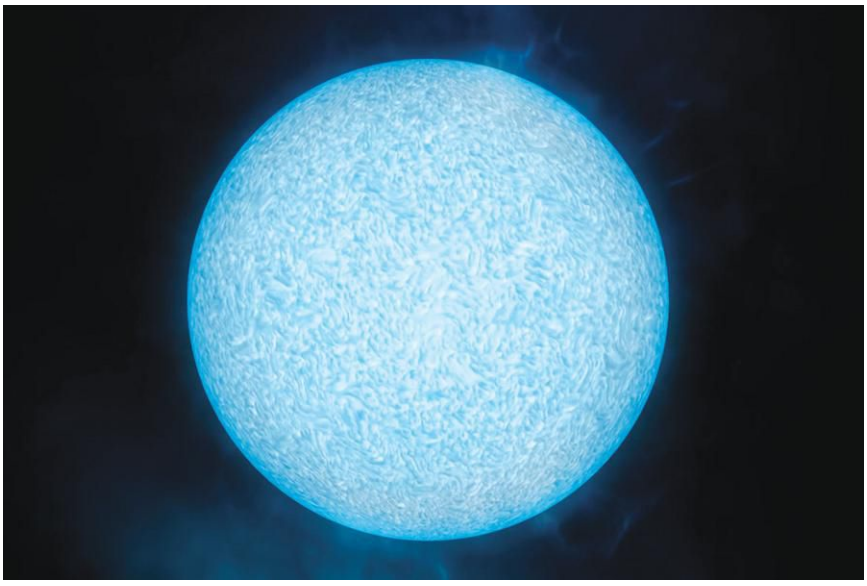
A NASA analysis concluded that the Jan. 18, 2024, crash of the Ingenuity drone on Mars was likely caused when its navigation camera lost its tracking ability while flying over a visually featureless surface. The report amounts to the first aircraft accident investigation on another world.

FILLING UP SPACE

China deployed the first batch of its planned 13,000-satellite Guowang megaconstellation with a Long March 5B rocket launch from Hainan Island on Dec. 16. Guowang is China's second megaconstellation currently under construction, joining the planned 14,000-satellite Thousand Sails.

DARK COMETS DOUBLED

A paper published Dec. 9 reports seven new dark comets — small solar system bodies that move as if they are comets with orbits altered by outgassing, yet display no detectable tail. The finds bring the number of known dark comets to 14. — MARK ZASTROW



FALSE YOUTH. Some hot, blue, young-looking stars, such as the one in this artist's impression, may actually be the result of a merger between two older stars. ESA/HUBBLE, M. KORNMESSER

Aging star rejuvenated by eating one of its own

HD 65907 IS A STAR that appears young. Based on color and brightness, it should be roughly 5 billion years old, like the Sun.

But HD 65907 contains much less iron than expected for a star of that age. This suggests it was born much earlier — when the universe was filled with the supernova debris of massive short-lived stars, but before longer-lived white dwarfs began to explode and scatter their iron-rich interiors.

Moreover, HD 65907 orbits the Milky Way's center out of step with most stars in the galaxy's disk. Instead, it has an elliptical orbit that takes it above and below the galactic plane, more typical of stars much older than those born in the galaxy's spiral arms.

To solve this identity crisis, astronomers fed archival spectral data of the star into calculations of synthetic stellar atmospheres, which return its most likely composition. Those models showed HD 65907 is lacking two critical heavy elements, lithium and beryllium. (By comparison, the Sun has 15 times more beryllium than HD 65907.) This means that HD 65907 cannot be a young star, as it would then contain those elements, which result from multiple generations of stellar lives and deaths. Furthermore, HD 65907's light shows a slight excess of infrared emission too cool to come from the star itself, but consistent with emission from a debris disk around it.

It seems that HD 65907 is the result of a merger of two much older stars, each born before the interstellar medium was as enriched with elements as it is now. When they collided, they created a larger, brighter, bluer star, essentially reigniting under an assumed identity.

With these pieces in place, the researchers declared HD 65907's true age: 11 billion years. Its apparent age of 5 billion years is the time since the merger. Work like this could help astronomers untangle the mystery of "blue stragglers" — stars that are brighter and bluer than expected for their age. The team's results have been accepted for publication in *Astronomy & Astrophysics*.

— PAUL SUTTER

ESO/K. OHNAKA ET AL.

A STAR'S DYING BREATHS

The red supergiant star WOH G64 is one of the largest and most luminous stars in the Large Magellanic Cloud, one of the Milky Way's satellite galaxies, 160,000 light-years away in the constellation Dorado. And after years of effort, astronomers at the European Southern Observatory managed to capture a remarkably detailed image of it with the Very Large Telescope Interferometer rooted in Chile's Atacama Desert, making it the first close-up picture of a star beyond our galaxy. Published Nov. 21 in *Astronomy & Astrophysics*, the work also provides a rare glimpse into the final moments of a star that will inevitably explode as a spectacular supernova. In 2014, the star went quiet after erupting for some three decades. All that expelled material now envelops the star as a previously unseen egg-shaped cocoon. The star has also dimmed significantly during the past decade, yet another indication of its imminent death. — SHARMILA KUTHUNUR

Fundamentals First Fund

An ETF
Symbol KNOW

Your money Carefully managed

Abstract

The Fundamentals First Fund, an ETF, is part owner of approximately 100 publicly traded worthy companies, and it owns publicly traded debt. These worldwide companies are vital, important, useful, or just plain nice to have around, and most have been pursuing their business course for decades. We individually select these companies with care and in a manner as to spread our risk so that no single company event can cause more than a bruise. Mason Capital has managed money this way for more than three decades. If you are more specifically interested in who we are, how we do it, and how you might participate, read on.

www.FundamentalsFirstFund.com

(Our Website Has a Lot About Us)

2/21/24 IPO Market Open:	$10.00
12/31/24 Market Close:	$10.72
Dividends Paid:	$ 0.14

Investors should consider the investment objectives, risks, charges and expenses carefully before investing. For a prospectus or summary prospectus with this and other information about the Fund, please call 617-228-5190 or visit our website at www.fundamentalsfirstfund.com
Investments involve risk. Principal loss is possible.
Quasar Distributors LLC.

10 MICRON astro•technology
MADE IN ITALY
ASTRONOMICAL MOUNTS

The first commercial mounts with integrated absolute encoders

USA and Canada Dealers:
www.10micron.com/dealers

THE NINE PLANETS RING
HANDCRAFTED WITH AN ORBITING GIBEON METEORITE BAND IN 18K GOLD SET WITH 9 GEMSTONES

NINEPLANETSRING.COM
831.336.1020

OBERWERK
High-Performance Optics for Earth & Sky

oberwerk.com

NEAF™ 2025
April 5-6

EXPERIENCE IT TO BELIEVE IT!

The World's Largest Space and Astronomy Expo

Rockland Community College, Suffern, NY

NEAF is an amazing extravaganza featuring over 100 of your favorite vendors, with huge discounts on merchandise and an incredible lineup of guest speakers. Plus: music, raffles, fun, and surprises.

FEATURING SPECIAL GUESTS:
HOOT GIBSON Veteran Space Shuttle Astronaut
EILEEN COLLINS First Female Shuttle Commander
TOM MULDER Boeing Starliner Mission Designer
BOB PAPPALARDO Europa Mission Project Scientist
PLUS: ARTEMIS, SPACEX
AND MUCH MUCH MORE!

ORDER TICKETS AT: NEAFexpo.com

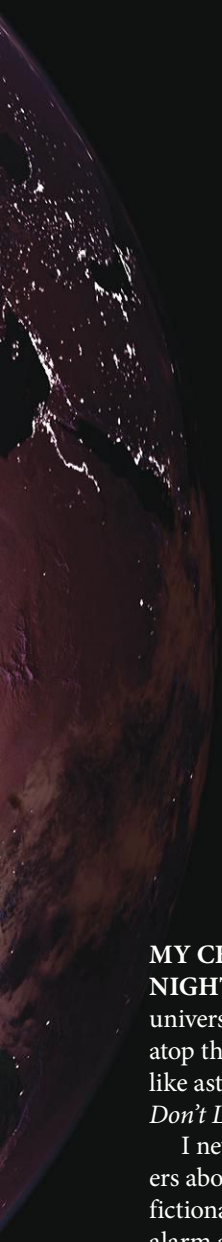
Presented by RAC ROCKLAND ASTRONOMY CLUB™
Sponsored by Astronomy magazine, DISCOVER
NEAF NORTHEAST ASTRONOMY FORUM™

Northeast Astronomy Forum & Space Expo

Don't miss NEAIC 2024! America's Premier Astro Imaging Conference. April 7-8, Visit NEAFexpo.com/NEAIC for more info.

SOLVING THE CLIMATE EQUATION

Most people worry about climate change, but few know what to do. The right tools allow us to convert scientific urgency into effective action. BY KATHARINE HAYHOE



This glowing image of our home planet combines multiple layers of imagery and data from several Earth-observing satellites. It not only showcases natural resources such as land, sea, and air, but also highlights human infrastructure. NASA IMAGES BY RETO STÖCKLI, BASED ON DATA FROM NASA AND NOAA

MY CHILDHOOD FASCINATION WITH THE NIGHT SKY led me to study astronomy and physics at university. By my second year, I was operating the telescope atop the physics building, tracking celestial objects — just like astronomy student Kate Dibiasky in the disaster movie *Don't Look Up*.

I never imagined I'd also soon find myself alerting others about the dangers my science revealed. Only instead of a fictional asteroid hurtling toward Earth, I was sounding the alarm about the climate crisis.

For decades, scientists have struggled to communicate the urgency of this real and actionable threat in a way that leads to meaningful change. I've learned the real challenge isn't a paucity of scary facts or worried people. Rather, it's connecting what we *know* with what we can *do* — turning knowledge into action. As former United Nations climate chief Christiana Figueres says, "We are only as doomed as we believe ourselves to be." Yet many people remain unsure of how to respond — and as a result, do nothing.

Changing course

My wake-up call began not at the telescope but in a class I took to fulfill a breadth requirement. At the time, I shared the same vague understanding of climate change most of us have. I knew it was real and human-caused, but I considered it a distant issue. Like a far-off chunk of rock in the asteroid belt, it didn't feel urgent or even relevant to my life.

Yet in that classroom — a relic of the '60s, with linoleum floors, beige walls, and those plastic molded chairs with attached desks — I was astonished to learn that climate change isn't a future threat. It's affecting us now. Even more surprising, I learned it's far more than an environmental issue. Climate change is deeply intertwined with human life on this planet, affecting our health, our food, and our water.

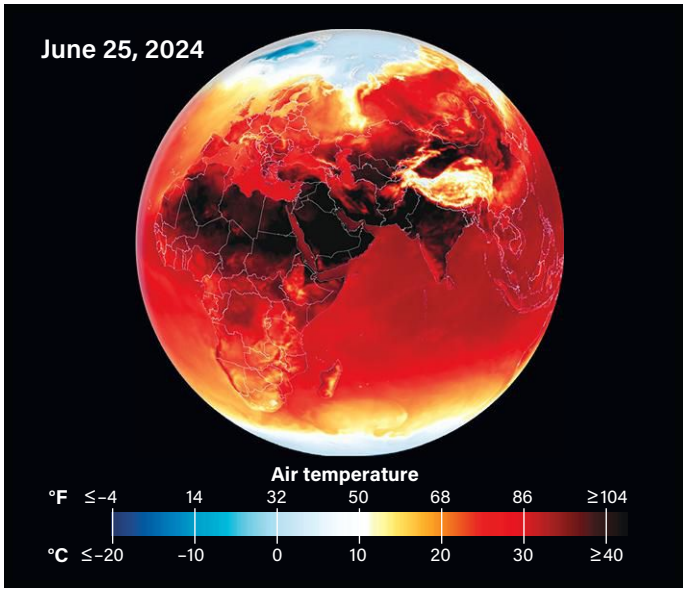
It drives economic instability and geopolitical conflicts, exacerbates refugee crises, deepens poverty, and disproportionately harms marginalized communities.

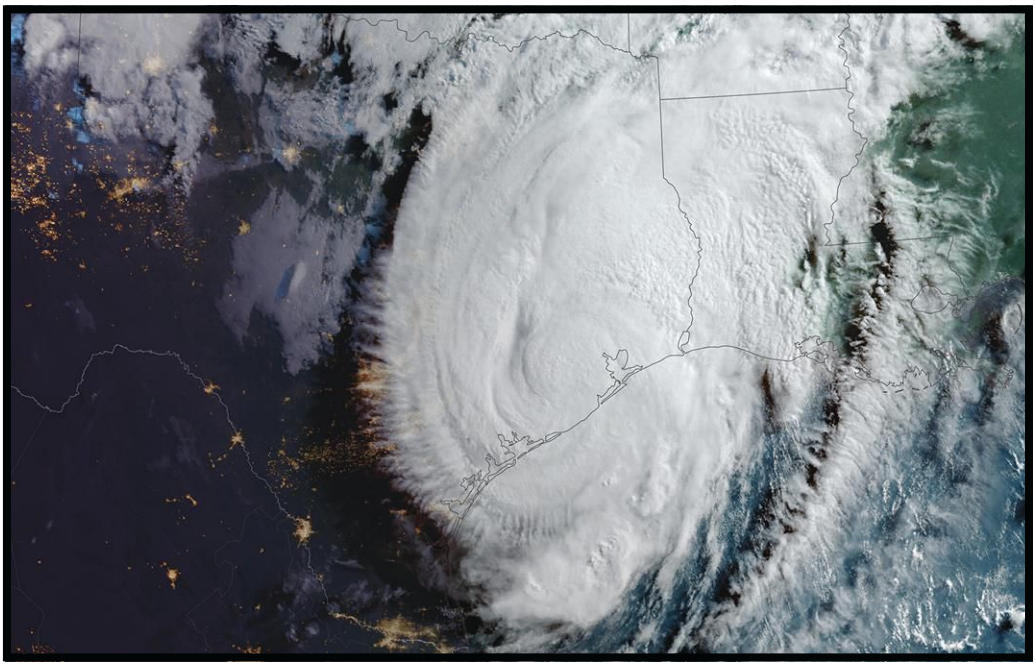
What amazed me most was learning that climate science required the very skill set I was already developing, from decoding the equations of nonlinear fluid dynamics to modeling planetary atmospheres.

"If that's the case, then how can I not help?" I thought. "Climate change is obviously urgent enough that we will fix it quickly, and then I can go back to studying the universe!" Encouraged, I changed course, applying to atmospheric science graduate programs focusing on research that helped decision-makers make the right choices. After all, surely they would do what we needed them to, once they understood the urgency and scope of the climate crisis — right?

Scientists had known since the 1850s that burning coal, gas, and oil releases heat-trapping gases, wrapping an extra blanket around the planet and causing it to warm. By the 1930s, this warming was already being detected in global temperature records. By the 1960s, the future implications were so concerning that scientists took the unprecedented step of formally warning a U.S. president — Lyndon B. Johnson — about the societal risks of climate change.

In the early 1990s, climate change impacts were starting to become visible. Yet my





BELOW LEFT: 2024 was the hottest global summer on record, according to NOAA (which has records dating back 175 years). This snapshot shows the air temperature on June 25, 2024. LAUREN DAUPHIN, USING GEOS DATA FROM THE GLOBAL MODELING AND ASSIMILATION OFFICE AT NASA GSFC

BOTTOM LEFT: A monstrous Hurricane Beryl makes landfall in Texas on the morning of July 8, 2024. The storm's intensity was fueled by warm ocean waters, which in turn were caused by climate change. WANMEI LIANG, USING GOES 16 IMAGERY COURTESY OF NOAA AND THE NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE (NESDIS)

CENTER: A changing climate brings with it increasingly devastating storms. This October 2012 photo shows some of the extensive damage left by Hurricane Sandy along the New Jersey coast. U.S. AIR FORCE

FAR RIGHT: Positive change is possible — and it is happening in places like the Bhadla Solar Park, located in the Thar desert near India's border with Pakistan. These reflective blue solar panels, imaged from space, are part of an installation that spans more than 22 square miles (57 square km), which harvests the free, clean energy of sunlight. LAUREN DAUPHIN, USING LANDSAT DATA FROM THE U.S. GEOLOGICAL SURVEY

optimism felt justified at the time. I had every reason to believe meaningful action was not only possible, but imminent. In 1988, NASA scientist (and former astrophysicist) James Hansen testified before Congress that global warming was real and already happening. The Intergovernmental Panel on Climate Change was established and, in 1990, released its first scientific assessment report. In 1992, just before I took that climate class, nearly every country in the world signed the United Nations Framework Convention on Climate Change, pledging to prevent "dangerous human interference" with the climate system.

The climate equation

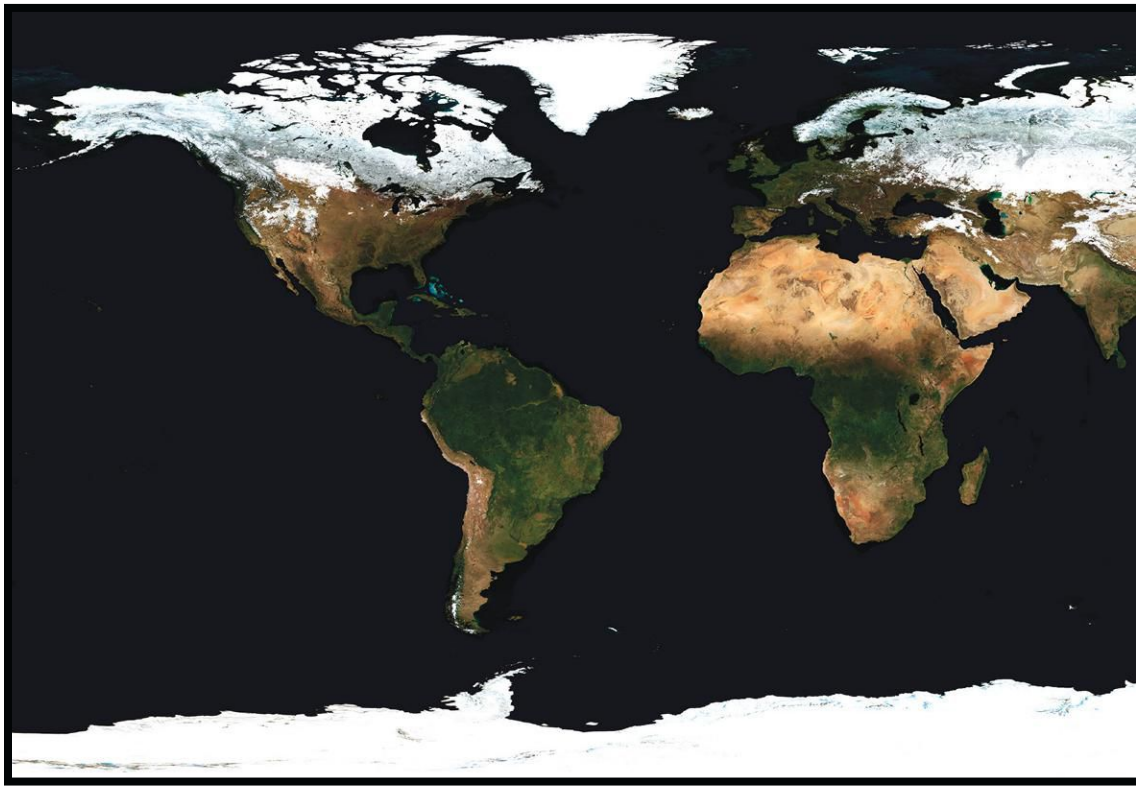
Yet here we are, 30 years later. There's been progress, yes — but at nowhere near the scale needed to avert this crisis. Shockingly, over half of all carbon pollution — the primary driver of climate change — has been emitted *since* 1990. This problem has only accelerated during the years I've dedicated my life to addressing it. It's no wonder so many scientists, including me, are frustrated and appalled at the inadequacy of society's response to the urgent threat we've identified.

In my case, though, that frustration drove me to search for the reason *why* understanding the science hasn't been enough to spur action. And it's this search that ultimately led me to the realization that the "climate equation" we've been using to guide our communication efforts is stunningly incomplete. To be explicit, it lacks two key terms that convert scientific urgency into effective action. How could we expect success without them?

Equations help scientists understand, predict, and solve complex problems. But when it comes to activating people to address climate risk, we've been relying heavily on one part of the equation while leaving out two essential terms. As a result, it's like trying to fix a complex machine with just a screwdriver, leaving the hammer and wrench untouched in the toolbox. Without these missing tools, our efforts have fallen short.

The first term, which has dominated our efforts for over a century, is physical science. I think of this as the head: everything we know, encompassing the data, facts, models, and observations we've meticulously gathered over decades

Shockingly, over half of all carbon pollution – the primary driver of climate change – has been emitted since 1990.



RIGHT: Imaging projects such as NASA's Blue Marble: Next Generation create high-resolution, time-stepped maps of Earth from space, allowing scientists to monitor conditions on our planet in many ways. From measuring precipitation and vegetation growth to monitoring wildfire and storm activity, these crystal-clear satellite composites are invaluable for researchers looking to study human-made change, both good and bad. This map shows the entirety of Earth in December 2004, during Northern Hemisphere winter. RETO STÖCKLI, NASA EARTH OBSERVATORY

BELOW: Scientists estimate that the warming climate and rising sea levels have increased the rate of natural land loss in Louisiana's Barataria Bay by up to 30 percent. The image at left was taken in 1985, and the image at right in 2020. LAUREN DAUPHIN, USING LANDSAT DATA FROM THE U.S. GEOLOGICAL SURVEY

and even centuries. This term provides essential information, like the fact that never in the history of this planet, going back hundreds of millions of years, has global temperature changed as rapidly as it is now. Earth has been warmer and cooler before, but the speed of today's changes and the fact that they're caused by human actions are entirely unprecedented. Climate science also reveals the existence of physical tipping points, critical thresholds that can lead to irreversible changes in the climate system, from ocean circulation shutdown to Amazon rainforest dieback.

But understanding the problem is only part of the equation. To solve it, we need a second term: understanding why it matters. I think of this as the heart. Why? Because knowing what's happening isn't enough. As much as we like to believe we're purely rational beings, the reality is that, as humans, we make decisions based on what we care about, not just what we know. The risks posed by climate change must be connected to what matters most to each of us — our health, homes, families, and future — or they are insufficient to encourage most people to act.

By now, the impacts are evident all around us. Heat waves are more intense and frequent. Wildfire seasons are longer, with blazes burning greater areas. Droughts are stronger and more prolonged. Hurricanes, typhoons, and cyclones are intensifying at record speed, powered by energy from record-warm oceans. Heavy downpours occur more often, as warmer air holds more moisture. And people are noticing these shifts: The U.S. now experiences at least one billion-dollar weather and climate disaster every three weeks, on average. In 2023, 9 out of 10 Americans said they'd been personally affected by extreme weather — or, as I call it, "global weirding."

Even still, many haven't yet made the crucial connection between what's happening and how it affects us personally. While nearly three-quarters of Americans acknowledge the climate is changing and are concerned about its impact on future generations, less than half agree that climate change will impact their lives. A similar gap between the head and the heart is evident worldwide. We understand intellectually that the problem is real and urgent, but haven't fully recognized how it will harm — or is already harming — the people, places, and things we love.

Make no mistake, that harm is already here. For example, did you know that the particulate pollution from fossil fuels alone is reducing the success of in vitro fertilization by 40 percent and contributing to premature births, as well as causing over 8 million

LEFT: Deforestation can significantly impact local weather, as illustrated by this satellite image of Alta Floresta, Brazil. Cloud formation — and thus, rainfall — is higher over land that has been cleared and cultivated (at right) than natural forest (at left). ROBERT SIMMON AND JESSE ALLEN, BASED ON DATA FROM THE MODIS SCIENCE TEAM

GETTING STARTED

UROS KOVANDZIC/DREAMSTIME.COM

The first thing everyone can do is to start talking about why climate change matters and what people can do. You may think this seems obvious, but two-thirds of Americans aren't having these conversations! And if we aren't talking about it, why should anyone care?

Connect the dots between both what you care about — whether it's your home, your pet, your child, your favorite outdoor activity, or the place you love — and how climate change is affecting it.

Join a climate action group to amplify your voice. Spark ideas for change at work, school, or any other group you're part of, from congregations to sports teams.

Hold politicians accountable at every level. City, county, and state or provincial officials all have significant power to make rapid decisions with substantial impact. But most elected officials underestimate how concerned their constituents are about climate change because they hear from them so rarely.

Consider where you keep your money — banks, credit cards, retirement accounts, investments — and use your voice to advocate for change there as well. And yes, reduce your personal carbon footprint — but don't forget to make those actions contagious by talking about them. *—K.H.*

deaths around the world every year? Breathing polluted air increases people's risk of lung and heart disease, stroke, type 2 diabetes, and more. And extreme heat not only drives up our power bills and increases the risk of heat stroke for people working or spending time outdoors, but it also affects our sleep and our mental health.

Then there's the economy, where inflation has driven up food prices; studies have fingerprinted the contribution of climate change to these price hikes. Specialty crops, from bananas to coffee, are under stress, and climate-related extremes wiped out much of the global cocoa harvest as well as significant proportions of the U.K.'s crops in 2023. Insurance rates are skyrocketing thanks to climate-related disasters, with some companies even pulling out of high-risk areas in Florida and California. On a global scale, climate change has already widened the economic gap between the richest and poorest nations, increasing the disparity by as much as 25 percent.

Even astronomy is not immune. As the atmosphere heats up, turbulence is on the rise. This affects air travel, increasing the risk of stomach-dropping bumpy weather, but it also affects astronomical observations from Earth's surface. Astronomers are already being warned that they need to incorporate climate-change projections into their site selections and prepare for an increase in poor viewing conditions.

This is how to make the head-to-heart connection: by talking about what's happening now, not in some abstract future; what's happening here, not "over there" in the metaphorically distant asteroid belt; and what's relevant to our lives, rather than to the polar bears or the ice sheets.

It's not just about global temperature or glaciers. It's about my kid's health, the air they breathe, and whether they can play outside. It's not only about sea level rise, but about disrupted commutes and skyrocketing insurance rates. And it's not only about carbon pollution levels, but about how the food we eat is getting less nutritious as faster-growing crops mean lower nutrient levels, and how our homes, roads, and buildings were designed for a climate that no longer exists. To care about climate change, we don't need to be scientists, environmentalists, or activists. We only need to be humans living on planet Earth.

Chances are, if you're reading this you're already being impacted, whether you know it or not. And that makes you the perfect person to care.

In our hands

Here's the thing, though: Connecting our heart to our head still isn't enough. Why not? Because the whole world could be worried, but if we don't know what to do, we'll do nothing. And that's where the majority stands today.

In the U.S., for example, two-thirds of people are worried, but only 8 percent are taking action. That means nearly 60 percent of Americans are worried about the climate but don't know what to do! That's why the third term in the equation is crucial: the actions we take in

response to our head and our heart. I think of this as the hands, and they are what will determine our future.

When it comes to climate action, there's no silver bullet. No single solution will fix everything. But there is plenty of what I like to call silver buckshot: smaller but meaningful solutions that, when combined, have the power to tackle this crisis and build a better world.

Imagine the atmosphere as a swimming pool. The level of heat-trapping gases is like the water in the pool. Before the Industrial Revolution, the water level was just right. But then we stuck a giant hose in the pool and ever since, we've been turning the hose up every year. Our emissions come from burning coal, gas, and oil, as well as through deforestation and unsustainable food systems. Now, the water's so high that our toes can't touch the bottom anymore.

So, what do we need to do? Three things: First, we need to turn off the hose. We can do this by improving energy efficiency, shifting to renewable energy, stopping deforestation, and making our food systems sustainable. This can include everything from signing up for a clean power plan for our home to advocating for sensible land use policies in our county, township, or region.

But the pool also has a drain: nature. By investing in nature, we can help it absorb carbon from the atmosphere and store it in ecosystems and soil. This means protecting old-growth forests, restoring damaged ecosystems, adopting climate-smart regenerative agricultural practices to turn our food systems into carbon sinks, and yes — planting trees, too!

There's one more step, though. The water level in the pool is already too high, and many people are suffering. Climate change affects us all, but not equally. The poorest and most vulnerable are the hardest hit. That's why building resilience — akin to teaching people to swim — is just as critical. We need to adapt our infrastructure, make our food and water systems resilient, and help people and nature adapt to the changes that are already too late to avoid. Whether improving disaster-response systems or greening urban areas to protect people from heat and floods, there are many ways we can build that resilience.

There's no silver bullet for climate change. But there is plenty of what I like to call silver buckshot.

There are so many options to turn off the hose, make the drain bigger, and learn how to swim, from building solar farms and public transportation to cutting food waste and educating overlooked women and girls. And the best part? Most of these solutions make the world better, full stop. They give us cleaner air, more abundant water, and more affordable energy. They protect us from the growing disasters caused by climate change, while also improving our physical and mental health. Many solutions also address poverty, reduce inequalities, and restore ecosystems rather than degrade them.

Using our voices

The systemic changes we need are clear, but they raise an obvious question: "What can *I* do about climate change?" After all, you might think, "I'm just one person, and not a particularly influential one."

This sense of helplessness and lack of agency is echoed in *Don't Look Up*, as scientists' efforts fail to change the course of disaster. Despite attempts to warn the public, the asteroid strike eventually wipes out life on Earth.

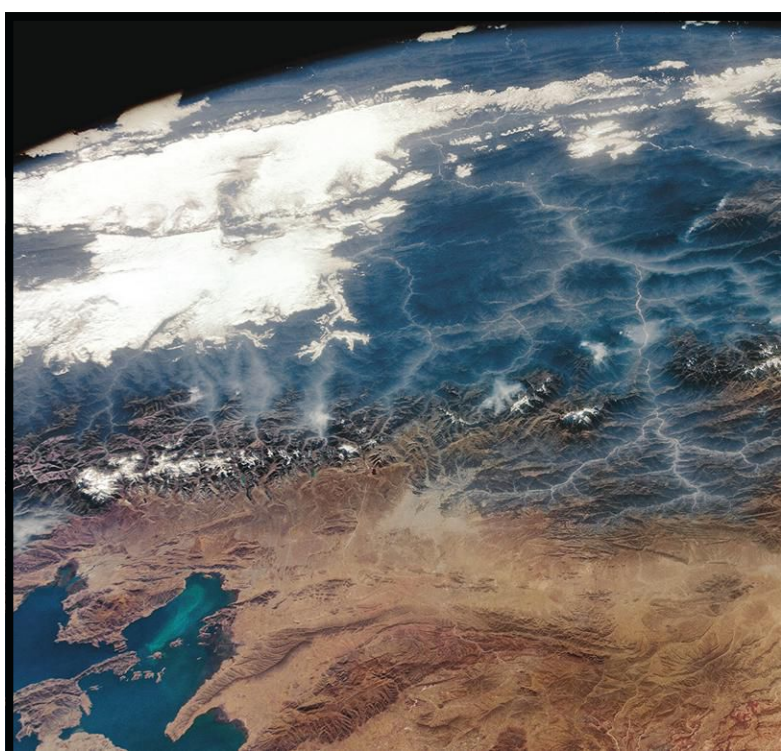
While this allegory offers no hope, history holds a different lesson. Large societal changes at the scale we need have happened before. And those who led these movements — from Susan B. Anthony to Mahatma Gandhi to Nelson Mandela — weren't rich or famous. But they used their voices, inspired millions more to use theirs as well, and they changed the world. Our lives are materially different because of what these individuals accomplished. If they could do it, so can we.

That's why, to transform the systems that shape our choices, I'm convinced our voices are the most powerful tool we have. Through our voices, our votes, and our choices, we can

BELOW: An astronaut aboard the International Space Station captured smoke rising from forest fires burning in numerous canyons along the eastern Andes Mountains. NASA/ISS CREW EARTH OBSERVATIONS FACILITY/EARTH SCIENCE AND REMOTE SENSING UNIT/JOHNSON SPACE CENTER

TOP RIGHT: According to a NASA study, the yearly rise in global sea level has been accelerating, driven by melting of the Greenland and Antarctic ice sheets. Projections based on the current trend suggest sea level will rise some 26 inches (65 cm) by 2100, heavily impacting coastal regions. KEL ELKINS, USING DATA FROM JASON-1, JASON-2, AND TOPEX/POSEIDON

BOTTOM RIGHT: Ship tracks, visible as the narrow, curved lines in this satellite image of the Pacific Ocean, are formed when water vapor clusters around aerosols in ship exhaust. Changes in global standards for the amount of sulfur in ship fuel, enacted by the International Maritime Organization in 2020, appear to have led to a reduction of air pollution associated with ships — and a subsequent reduction in ship tracks. JOSHUA STEVENS, USING DATA COURTESY OF YUAN, T., ET AL. (2022) AND VIIRS DATA FROM NASA EOSDIS LANCE, GIBS/WORLDVIEW, AND THE SUOMI NATIONAL POLAR-ORBITING PARTNERSHIP



help make the best and most sustainable options for individuals the most accessible and affordable, too. Charging an electric car should be easier than finding a gas station. Healthy food like fresh fruits, vegetables, and sustainable fish should cost less and be more readily available than fast-food burgers made from meat farmed on what used to be Amazonian rainforest. Energy-efficient appliances should be cheaper than wasteful ones, and repairing what we already own should be simpler than buying new things. And all electricity should be clean — we shouldn't even have to think about that!

As individuals, our actions absolutely matter. But for real change, we must look beyond our personal carbon footprint. It's not only about our own behavior — it's about creating the conditions that make sustainable choices the easiest and most obvious path for everyone. As environmentalist Bill McKibben puts it, "The most important thing an individual can do right now is not be such an individual." Collective action is far more powerful than isolated efforts.

Together as one

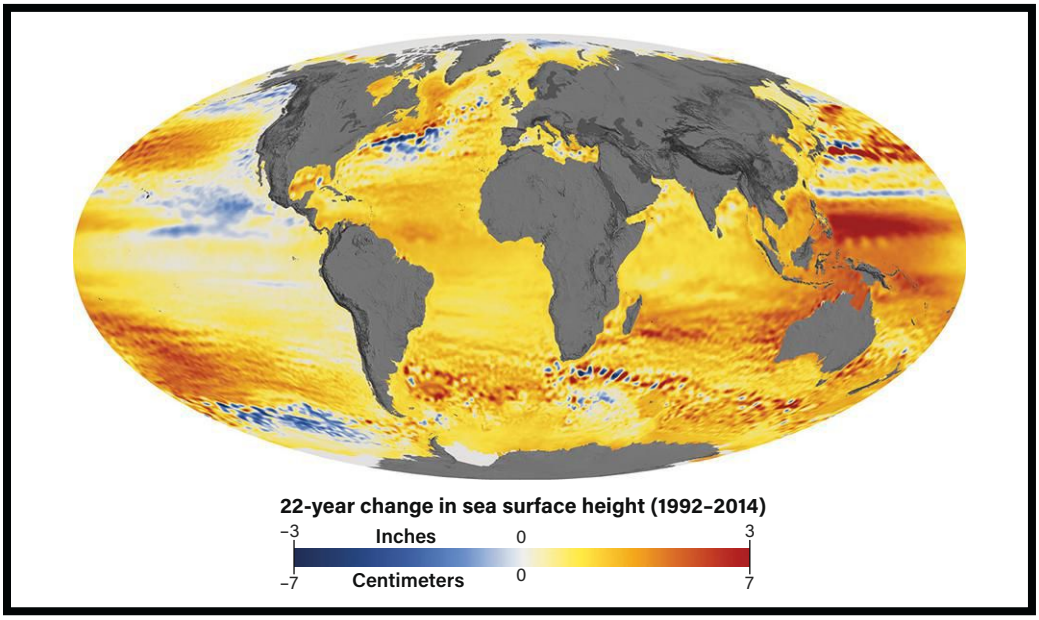
How do we ensure these solutions happen sooner rather than later? Research identifies social tipping points that can catalyze systemic change: removing fossil-fuel subsidies, divesting from assets linked to fossil fuels and revealing their moral implications, building carbon-neutral cities, and strengthening climate education and engagement.

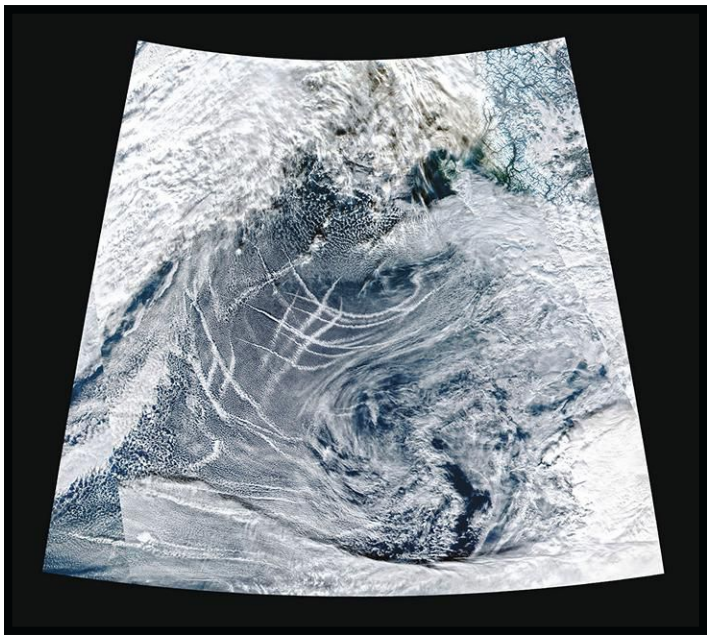
As individuals, we have a role to play in this process. Who is lobbying organizations stop investing in fossil fuels? Who is highlighting the moral costs of dirty energy and their impacts on our health and our future? Who is advocating for the sustainable city programs and practices, from bike lanes and high-density development to clean energy and composting, needed to become truly carbon-neutral? Who is pushing for climate education and — when a school or a university adopts it — making it happen? The answer, in each of these cases, is individuals. The success of systemic change relies on individuals advocating for these changes at every level of governance and society.

For years, I felt the weight of a crisis too vast to fix alone. I struggled to understand why knowing the science wasn't enough. But now the equation is clear: We must connect our heads to our hearts, then turn that urgency into action with our hands.

As Jane Goodall says, "only when our clever brain and our human heart work together" can we create the momentum needed to tackle the climate crisis and build a better, safer, healthier, and greener future. That is the world I want — for my child, for myself, and for everyone who shares this planet with us.

We can't stop the climate asteroid alone. But I'm certain we can do it together.





Climate scientist **Katharine Hayhoe** *is a distinguished professor at Texas Tech University and chief scientist of The Nature Conservancy.*

How to build CLIMATE

Tony Fadell invented the iPod, co-invented the iPhone, and co-founded Nest. His follow-up? Turning down the heat for the entire planet. BY MARK ZASTROW

IN MANY WAYS, TONY FADELL BUILT THE DIGITAL WORLD WE LIVE IN.

At the turn of the millennium, his efforts to build a pocket-sized, hard-disk-based device that could hold 1,000 songs in MP3 format caught the attention of Apple. Within months, he had been hired by the firm, and less than a year after his first phone call with Apple, the iPod had been revealed and was shipping to customers.

Fadell then went on to play a key role in the creation of the iPhone, overseeing its hardware. And after he decided in 2008 to leave Apple, he co-founded Nest Labs, reinventing the thermostat and ushering in the era of the internet-connected home.

But after leaving Nest in 2016, Fadell pivoted and started Build Collective — a fund that advises and invests in start-ups building solutions to address some of the world's biggest problems, including the climate crisis.

He was also instrumental in the creation of MethaneSAT, the most ambitious satellite to ever be built and run by a nongovernmental organization (NGO). Operated by the Environmental Defense Fund (EDF) in collaboration with the New Zealand Space Agency, the satellite launched March 4, 2024, to monitor emissions of methane — a greenhouse gas estimated to trap 28 times as much heat as carbon dioxide over the molecules' lifetimes.

Fadell spoke with *Astronomy* about building climate solutions, the relationship between space exploration and environmentalism, and what gives him hope in the face of the climate crisis.

LEFT: **TONY FADELL** was instrumental in the creation of the iPod, the iPhone, and the Nest Learning Thermostat. WILLIAMSON ADAMS; APPLE (2); NEST LABS

RIGHT: **THE ICONIC "EARTHRISE"** photograph, taken by Apollo 8 astronaut Bill Anders, is credited with helping to spark the modern environmental movement. NASA

SOLUTIONS

COAL MINES — like this one in Hailar, China — can result in the complete transformation of landscapes to feed global energy consumption. HERRY LAWFORD/WIKIMEDIA COMMONS (CC BY 2.0)

How do you see the climate state of play right now? What's the scale of what needs to be done to reign in global warming?

The first thing is, this has been a problem that has been created over the last 150 years. But the scale of the change we need now cannot take place over another 150 years.

We have to change everything all at once. We have to get to Industrial Revolution 2.0, which means everything that flies, floats, rides on the land, it all needs to change. How we do agriculture, materials, textiles — every single thing that came from Industrial Revolution 1.0 needs to be touched in 2.0, and a lot of it very dramatically.

That said, I have been investing and working in this space since about 2008, when I had kids — post-iPod, post-iPhone, kind of Gen-1 Nest. And what I have seen since then is that we really do have the technologies to abate and stop emissions of greenhouse gases like CO_2 and methane. And in almost all cases, it's more economical and better for the businesses who would implement them, from a return-on-investment perspective.

The issue is the high amount of capital and people and investment that is required to change the fundamental economic powers that be, whether that's a government or the champions in any one industry. Nobody wants to change because they want to protect their spot.

So, we have the technology we need, yet we have this inability to want to make the change — even though it's an existential crisis — because people want to continue to protect themselves. They understand that they have something to protect in the short-term — and the long-term, they don't want to see.

And so, we have a problem of will, not a problem of technology. It's human will, to be able to make those changes.

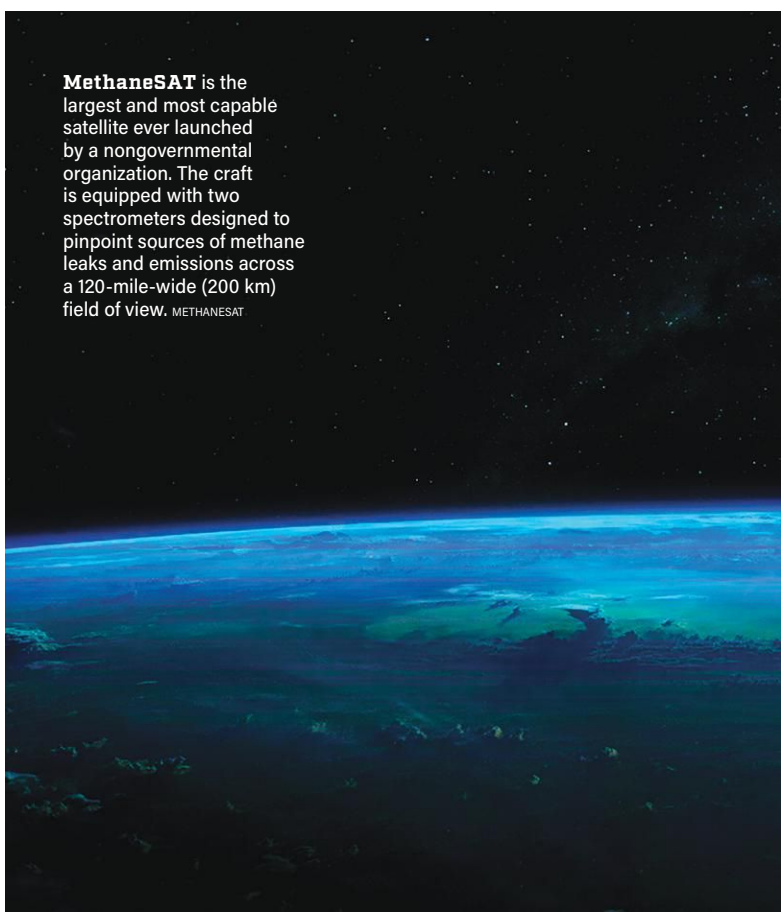
The problem that we have in democracies is that we have factions and no one wants to compromise in the middle. And so, it takes real adults in the room who all agree there's a problem.

At the corporate level, even though it's a better outcome businesswise, it means compromising the position that you're in. Investors and stakeholders don't want the state of play to change, or lose their valuable stock because they're going to have to really ramp up their spending to make the changes necessary.

And then governments, for the most part, in democracies — which are, especially in the U.S., driven by political donations — are aligned with these large corporate interests who do not want things to change because that means work.

These people have been maintainers. They are not builders. They're very different. So, we need the right incentives from government to encourage more and more builders to do these things while not continuing to subsidize the old habits that have gotten us into this problem.

Now, we're getting pointed in that right direction. We're seeing that change in certain places, like Norway — it's incredible what Norway's done. Now, on the road, there are



MethaneSAT is the largest and most capable satellite ever launched by a nongovernmental organization. The craft is equipped with two spectrometers designed to pinpoint sources of methane leaks and emissions across a 120-mile-wide (200 km) field of view. METHANESAT

> **We have a problem of will, not a problem of technology.**

more fully electric vehicles than there are gas-powered cars. And that's on the road, not being sold. What's being sold is over 90 percent electric. And it's not just electric cars, they have excellent mass transit as well.

So, it can be done. It's just a matter of the will to do so and to make those changes and for people to understand that it's going to impact things, but that it's for the greater good of the planet — as well as for their next generations that they spend and invest so much time and care in to raise.

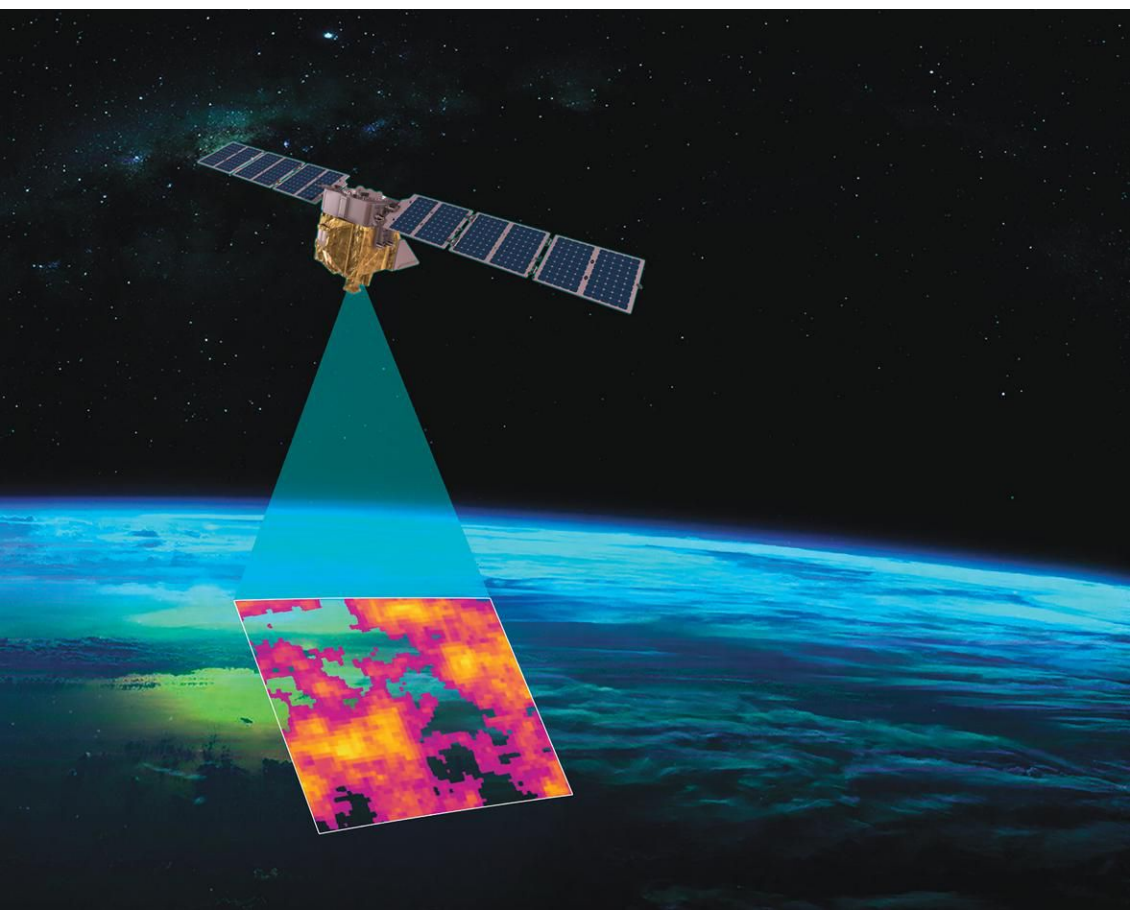
After leaving behind tech products like the iPhone and Nest, why did you move into the climate space?

I've always cared about the planet. My grandfather taught me how to garden and trim trees and was always taking me out in nature. So I always had a love of it — it really is me, it's in my person. And I woke up to the issue really in the mid-2000s, around the time of Al Gore's documentary, *An Inconvenient Truth*.

I also started seeing the problem when I was working on the iPod and iPhone and traveling to China. I saw how China was just gobbling up the earth that they had. Every time I went, I'd be like, "Oh my God, all this has changed, all this has changed." And I thought, "Wait a second, where's the balance in all this?" I'm not saying that they shouldn't do what they should do in China, I'm just saying that we need to have a bigger perspective on this.

So I was hearing about the problem, I was seeing the problems being created, and I thought, "How do I get involved?" And when I started learning more, I was like, "Wow, there is amazing technology that we need to deploy. And these are actually more profitable businesses when you do it right. Wait a second, it all aligns, it can be a win-win-win." And with the scale of the change — larger than the first Industrial Revolution — I thought, "Yes, we can do this."

If I had been around at the Industrial Revolution at the beginning, I would have been like, "I want to be part of this, everything's going to change." Well, guess what? We have the exact same thing, and the incumbents aren't the ones who are going to necessarily fix this. This is not a little thing, this is a huge thing, transformative in every single nook and cranny of our industrial world, and to me, that's opportunity.



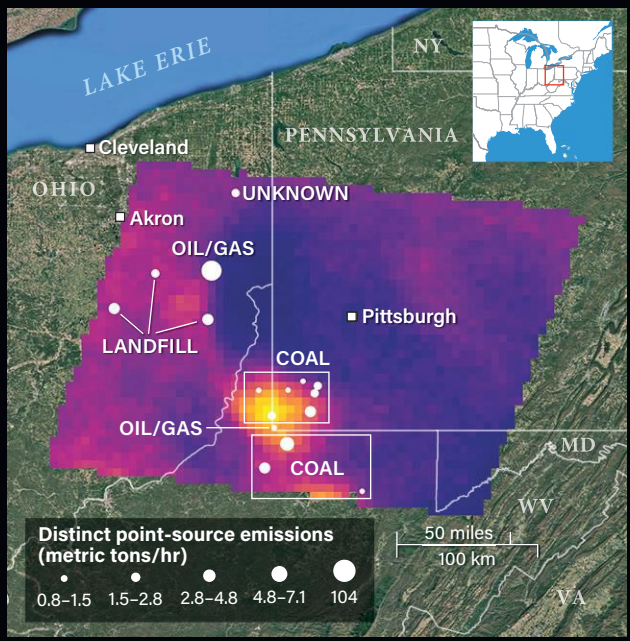
One thing you've helped to build recently is MethaneSAT. Can you talk about how you got involved?

The Environmental Defense Fund called me because I had been working with them on other projects from the perspective of a donor. This was the first time they were trying to launch a satellite. That's a very, very high-capital expenditure, and you've got to maintain it for 10, 15, 20 years while it's in space. It's not just a one-time expense, it's a continual annual expense. And so they wanted to do something that no NGO had ever done before — not to this level.

So, they were asking for advice on building a business, how to maintain it and sustain the satellite after it launched. There were a lot of brainstorming sessions to figure out the business model — how to get an NGO to have a for-profit business to pay for it while still making the data available for free, because that's what the NGO's mission is.

And so, I got involved very early on because Fred Krupp, who runs EDF — and he's been a visionary for more than 30 years on climate — asked for my help. And then

EYE IN THE SKY



MethaneSAT's data indicate this region near the borders of Ohio, Pennsylvania, and West Virginia emits 226 metric tons of methane every hour. METHANESAT; BASEMAP: GOOGLE EARTH

METHANE EMISSIONS are the second leading driver of climate change behind carbon emissions, but detailed data on where they originate are lacking. Many methane emissions are the result of leaks in natural gas or oil production; in addition to the environment, companies also stand to benefit if they can identify and stem leaks in their infrastructure.

MethaneSAT can precisely hone in on such leaks, as well as other sources of methane emissions like landfills. It can also measure how widely emissions disperse across regions. The satellite is designed to capture the "whole picture of emissions," including "both big sources and thousands of smaller ones," said mission lead Steven Hamburg in a statement Nov. 16, 2024.

Early results released by the Environmental Defense Fund indicate that emissions in North America and Central Asia are "significantly higher" than current engineering estimates. For instance, MethaneSAT observations of Utah's Uinta Basin — a region with leak-prone infrastructure — shows a methane loss rate of around 9 percent. The Appalachian region (show above) exhibits a loss rate that is 10 times lower. Still, it far exceeds industry commitments to target a loss rate of 0.2 percent by 2030. *—M.Z.*

we got other like-minded technology and business people around the table to try to help solve for this.

And we've launched the satellite and it's up and it's working and it just started reporting data after the calibration period in August. It is doing actually better than we thought it was going to do. It's exceeding expectations for numerical quantification of these leaks.

What's the significance of MethaneSAT, and how do the different pieces of this business model work?

The first and most important thing is having a third-party source of truth — someone that's trusted, not paid off by a governmental agency or an industry agency or whatever else. This is a third-party eye in the sky that is not beholden to any one group except the population at large.

Then after that, we have different levels of data. There's raw data that you can get from the satellite. And then there are all the other levels of turning that data into information. And because that takes compute [computing resources] and that takes real work and energy to create, those levels of information become our tools from which to derive revenue.

We can offer this information to third parties who are interested, whether that's governments, whether that's other NGOs who are fighting climate change, whether that's industries — either industry groups or individual industries like oil and gas, obviously, or agriculture. Stock traders, too — they want to know if there's going to be fines levied against oil and gas or agriculture, because those are the main ways methane is produced.

So going from raw data to information, that's where value is achieved. And because we know the satellite and how it works, we can turn the raw data into discrete information.

You can have the raw data for free, and anyone can get that. But as we turn it into information, then it becomes more valuable. And that allows us to then use it for marketing purposes — and for disclosure purposes.

It's the first time it's ever been done. And that's what's so extraordinary about what the EDF and Fred have pulled off.

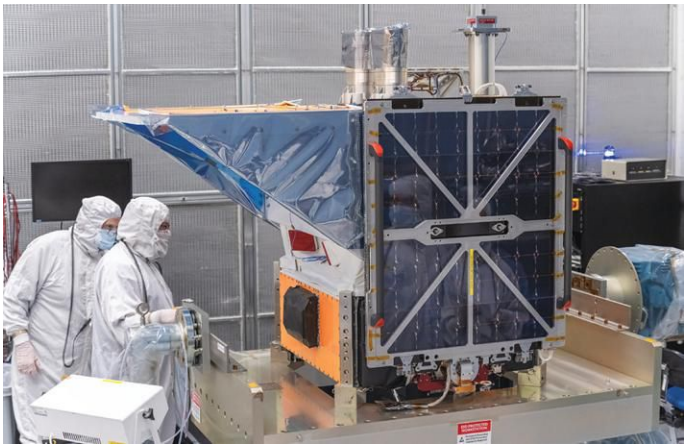
In spaceflight, we used to only talk about government agencies, right? Then we began talking about commercial spaceflight. And now there's a third space sector, of NGOs. And I hope it's inspired more NGOs to want to do this as well, to put eyes in the sky for whatever else needs to be watched.

There's obviously a big historical connection between spaceflight, astronomy, and the environmental movement. How do you think about space exploration and how it relates to solving environmental issues here on Earth?

I think there's two ways of looking at it. You know, I'm fascinated by space because we can go out and look back. There are other people who just want to keep looking out, and not look back.

For me, space is interesting, and there's all kinds of questions to be asked about the universe. It's great, and I love reading *Astronomy* and other things to learn about that stuff, because it's fun to do. But to me, that is a hobby and not an imperative.

When we're pointing things back at Earth and they're eyes in the sky that are helping us to solve problems on Earth, that's when it gets very interesting for me. That's when it turns from a hobby into something I will dedicate my time and energy to — to help someone and fund businesses and things of that nature.



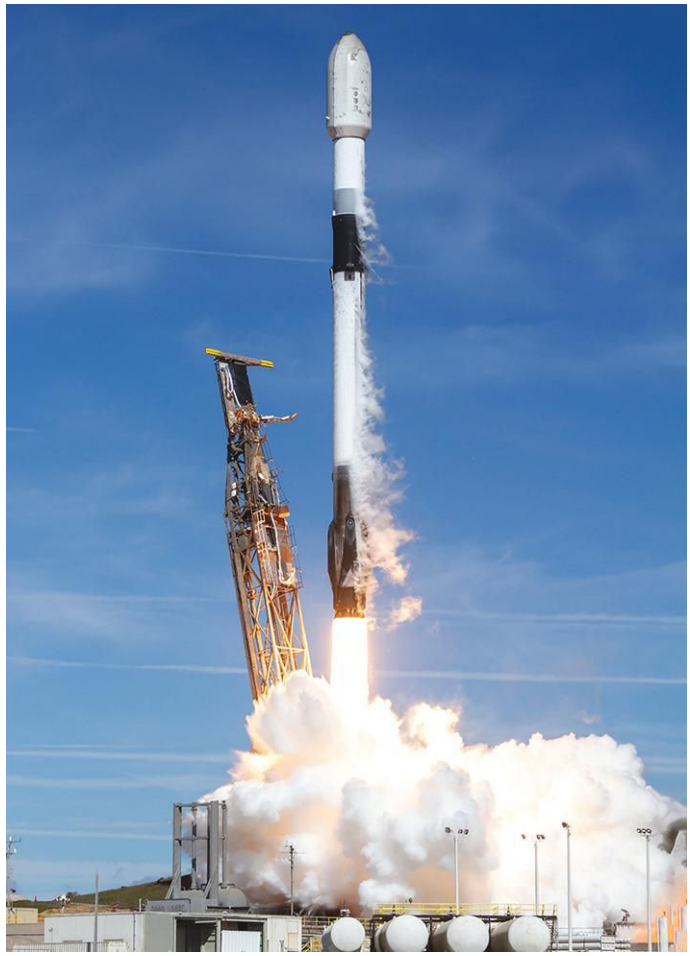
MethaneSAT is pictured in its clean room in Colorado prior to being shipped to California for launch. BAE SYSTEMS

I'm not funding the next mission to the Moon or Mars, but I will fund and work on things that are going to help us to improve health, our societies, and our environment here on planet Earth.

How important is it to you for humanity to become a multiplanetary species?

This is how I think about things of that nature: If we're not healthy in the stuff we're doing now, don't distract yourself. If we're not healthy, why are we doing this? Let's make sure we're stable and good here and really do the things we need to get done and not distract ourselves from what's most important with shiny objects like going to Mars.

The only thing that I thought is really interesting about going to Mars is that, ironically, we're going to learn how f------ good we have it here on Earth, and how horrible it is to go live on another planet without anything. I mean, Mars has got nothing compared to what we have here. We are living in abundance, incredible abundance everywhere — even in



ABOVE: **MethaneSAT** launched to orbit aboard a SpaceX Falcon 9 rocket from Vandenberg Space Force Base in California on March 4, 2024. SPACEX

TOP: **LANDFILLS** — like this one in West Java, Indonesia — are filled with organic material that releases methane as it decomposes. Globally, landfills account for roughly 10 percent of methane emissions. In some regions of the world, regulations require that landfill operators capture this methane for conversion into energy. TOM FISK/PEXELS

> **"The alternative is not to have hope, in which case, you might as well just go to Mars."**

Antarctica, compared to freaking Mars!

So maybe it'll make us all wake up and go, "This is a lot harder than we thought, and we should appreciate what we have."

When it comes to spaceflight, I love the fact that the "Earthrise" photograph and these kinds of things can give us perspective on who we are as a species — that is what's powerful. And not just the wonder and awe of where we are in the universe, which is beautiful, but also the destruction we're doing to the planet that we don't know about in our little daily world, versus what's happening on the planet at scale.

And when you have data transparency and you can start to project those data, you can start to get a whole sense of what's going on on this planet. I love to see it — not because I love to see maps of things like warming and deforestation, but I love to see it so that it motivates us.

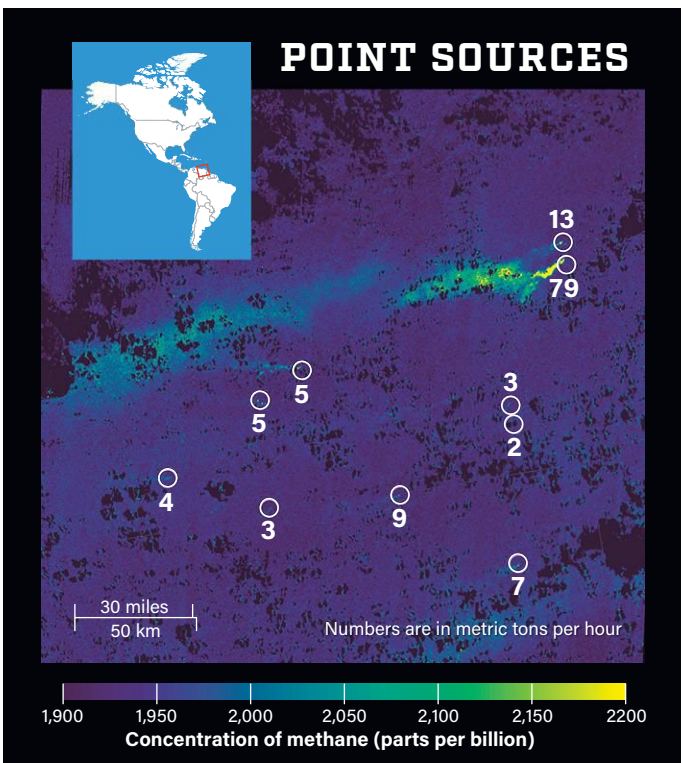
I bet when we bring a global perspective to people, and how we are this virus on this planet, people will go, "You know, I understand I'm going to make my individual change, but man, we really need to get over this issue of collective will to get moving." And I think that only comes from having a wider perspective. And that comes through education, and education comes through information and data transparency, and that can only be done from these things that are looking back at us.

You've written a lot about not just building products, but building teams — teams that have a sense of common purpose. How do we scale that to society writ large, and unite ourselves to solve a global problem like climate change?

It always takes one — one person, one product, one company, one mission. And when someone does something bold, and if that's successful, that emboldens the others who are around them to go, "Wait a second, they can do that, I know that guy, I knew that girl, I knew that one, they went to school with me, I could do that. If they can do it, why can't I do it?"

So it takes that movement, and my hope is that we're going to see a lot more of it — now that we're at this second or third generation of climate-crisis-focused businesses — that you're going to see these break out, and they're going to be unicorns and decacorns [terms for a privately-held company valued at $1 billion and $10 billion, respectively] and all that stuff, and people think, "I want to do that too."

You know, Nest was that in a way — we were saving energy and saving lives [with the Nest smoke detector], and a bunch of people and startups all spawned up from it. I'm hopeful that we're going to see another crop, and this



SINGLE SOURCES of methane are visible in this swath of Venezuela observed by MethaneSAT. Clouds, visible as dark patches, also dot this image. While such cloud cover would give other satellites difficulty, MethaneSAT's wide field of view combined with its high spatial resolution allows it to identify methane sources (circled) in between the clouds. The numbers next to each source indicate the rate of emission in metric tons per hour. METHANESAT

OIL AND GAS PRODUCTION FACILITIES vent excess natural gas from wellheads. This gas is often burned to reduce the amount of methane that escapes, as shown here at vents in the Bakken formation in North Dakota. But simple combustion is inefficient and inevitably releases methane into the atmosphere. ALAN GORCHOV NEGRON, UNIVERSITY OF MICHIGAN AND YULIA CHEN OF STANFORD UNIVERSITY

SPACE AGENCIES AND COMMERCIAL FIRMS alike are working toward a sustained human presence on Mars — but it won't be easy. NASA

is going to be bigger and bolder than ever, and that it becomes this avalanche, snowball effect, that there's going to be more and more and more.

And so that's my hope. And the alternative is not to have hope, in which case, you might as well just go to Mars.

So what do you see that gives you hope?

What gives me hope is we have the technology, and we have a new generation of people on this planet who do understand that they're going to live with these problems that we and our forefathers and mothers created, and they want to do something about it.

And you can see it in many people who are not just rushing to go into banking, or whatever it was in the 80s — you know, quick money. They care about the mission and what they're working on, what they're investing their time and energy into. They're a big force for change inside of organizations, as well as building new ones.

That's what gives me hope. And in politics — I'm looking around the world and seeing younger candidates. These old, old politicians are aging out, and we're going to see change.

It's just, is it going to be soon enough? But we are making more progress than we were five, 10, 15 years ago.

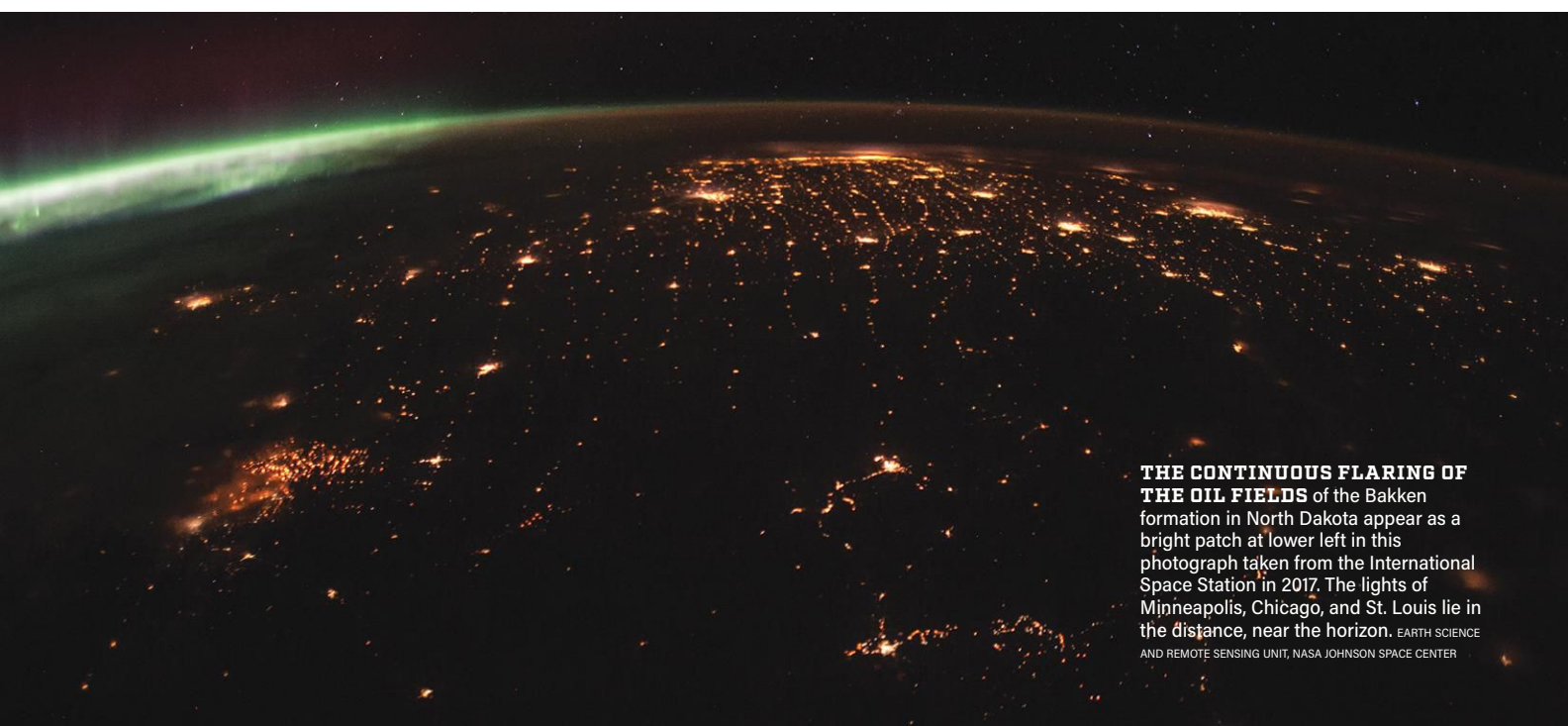
We have to get large institutions and systems to continue to act. The Inflation Reduction Act was a great one. We have to keep the faith and keep on moving and get more eyes in the sky to give us perspective on who we are as a species and what we're doing to this planet. There are a lot of good people in this world and they want to do the right thing — they just don't know how.

Look at when COVID happened — we got our s--- together, to a certain extent. I'm not saying it was perfect, by any means! But man, the world went, "Oh, we need these solutions — now." We need that kind of thing for climate change. But we can't wait and do it at the end. You can't reverse the effects of climate change when everything is underwater.

You can either be hopeful or not. And I've seen so many things to give me hope over the last 15 years. I wouldn't be having a hopeful conversation with you unless I've seen real change and real progress.

Is it enough? No. But could we get there? Well, the trend seems to be going in the right direction.

Mark Zastrow *is a senior editor of* Astronomy.



THE CONTINUOUS FLARING OF THE OIL FIELDS of the Bakken formation in North Dakota appear as a bright patch at lower left in this photograph taken from the International Space Station in 2017. The lights of Minneapolis, Chicago, and St. Louis lie in the distance, near the horizon. EARTH SCIENCE AND REMOTE SENSING UNIT, NASA JOHNSON SPACE CENTER

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.
BY MARTIN RATCLIFFE AND ALISTER LING

Two Lyrid meteors streak away from the shower's radiant in this 2023 photo. Also visible is a dim aurora to the northeast. ALAN DYER

Lyrid meteors dazzle

The planets offer exciting views in April. Jupiter is a brilliant object in the evening sky, although the observing window narrows as the Sun sets later each day. Mars is past its best, but remains bright and high in the sky. Mercury, Venus, and Saturn make an early-morning appearance before sunrise. And a special treat is the annual Lyrid meteor shower, which peaks in the month's third week.

Early April is your last chance to spot **Uranus**. It's a binocular object shining at magnitude 5.8 near the border between Aries the Ram and Taurus the Bull.

Scan about 4.5° south of the Pleiades (M45) with 7x50 binoculars to find a pair of 6th-magnitude stars lying east-west. These are 13 and 14 Tauri. Now, move 3° southwest to find a dimmer pair of stars, wider in separation, also lying east-west. On April 1, Uranus stands less than 1° northwest of the westernmost star of this second pair. By the 15th, it stands 0.9° due north of the same star.

Uranus is brighter than the stars and easy to track with binoculars. Catch it early, because it sets within two and a half hours of sunset on the 15th and becomes lost in twilight by the end of April.

The window for observing **Jupiter** narrows this month as later sunsets impact dark time. On April 1, Jupiter stands 46° high an hour after sunset, and sets by 1 A.M. local daylight time. On April 30th, it's down to 24° in altitude an hour after sunset and sets nearly an hour before midnight.

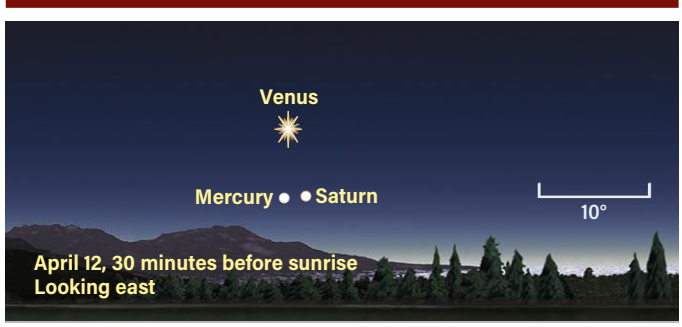
Jupiter's brightness dips 0.1 magnitude over the month to reach magnitude –2.0. Still, it dominates the constellation Taurus, already chock-full of gorgeous sights like the Hyades, Pleiades, and the red giant star Aldebaran. On April 1, a crescent Moon, complete with earthshine in late twilight, stands 3° east of M45. This is such an evocative scene that you will want to sit and watch as they slowly set in the west.

You'll find Jupiter and the thin crescent Moon side by side April 2, and again on the 30th.

Jupiter's apparent diameter, easily viewed through any telescope, declines from 36" to 34" during April. The planet's cloud belts are evident at a glance, but don't settle for the two dark equatorial belts. Patient viewing allows your eye to get used to seeing subtle shading on the planet and reveals a wealth of detail, particularly during moments of good seeing.

Jupiter's Galilean moons continue performing, orbiting the planet in periods ranging from two to 17 days. The inner three, Io, Europa, and Ganymede, have

Standing together



Let Venus guide the way to Mercury and Saturn, standing side by side, in the early-morning sky April 12. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

MERCURY and **SATURN** are side by side April 12, 2.2° apart.

resonant periods, with Europa and Ganymede continuing a series of events from last month.

On April 1, you'll find Europa and Ganymede some 10" apart to the east of the planet's disk. Seven days later, on the 8th, they are back together, now 18" apart to Jupiter's east. The pairing occurs again on the 15th, when they stand 30" apart; on the 22nd, they're 40" apart. Finally, on the 29th, the two moons are 55" apart. Each of these near conjunctions occurs a greater distance east of the planet.

An interesting Ganymede event occurs April 5, when it reappears from behind Jupiter's disk around 10:22 P.M. EDT (this occurs in twilight in the Mountain time zone). Just over two hours later, Ganymede enters into Jupiter's vast shadow, which extends to the east of the planet from our earthbound perspective. Watch the moon slowly fade out, starting just before 11:30 P.M. CDT (note the time zone change) and taking several minutes to disappear. Jupiter is getting low in the Midwest, so the eclipse is best seen from the Mountain and Pacific time zones.

Io undergoes many transits, orbiting the huge planet in 1.77 days. The moon and its shadow are crossing the disk as night falls in the mid-U.S. on April 11. Io exits at 10:46 P.M. EDT,

— *Continued on page 34*

RISING MOON | On the edge

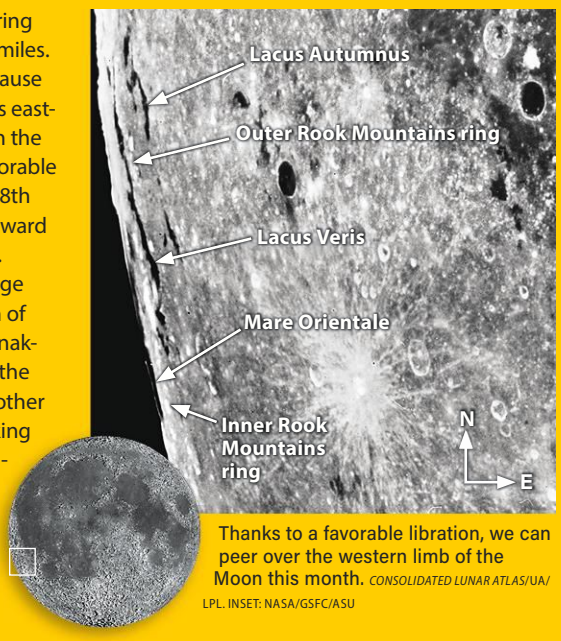
THE MOST STRIKING impact basin on the Moon is arguably Mare Orientale, a sea of frozen lava surrounded by a huge, well-defined double ring of rugged mountains that spans almost 600 miles. You're forgiven if you haven't heard of it, because it is tucked far against Luna's western limb, its eastern ramparts and lava lakes visible only when the lunar spin and elliptical orbit line up. This favorable libration (apparent tilt) occurs between the 18th and 24th, and similarly for the next month toward Third Quarter, but not again for another year.

Orientale is all about observing at the edge — literally. We're peering over the raised rim of the Cordillera mountains to view a narrow, snaking form of lava named Lacus Autumni. Use the recognizable Grimaldi to orient yourself. Another dark, long line is Lacus Veris. We're now looking beyond the tall ring of the outer Rook mountains into the shallows where lava welled up from below, then onward until we reach the light colors of the lunar crust pushed up into the inner Rooks.

Tucked right against the limb is the darker central floor of Mare Orientale. When Orientale formed, the denser mantle underneath bulged upward, creating a mass concentration. This so-called mascon affects spacecraft orbits, causing a slow shift in response to the extra gravitational force. Sunlight angles can make all the difference when observing. The picture here shows the back inner wall of Orientale (longitude 100 west) as the thinnest of white lines on the very limb, illuminated by a late-morning Sun in the lunar sky. If it was late afternoon, that wall would be in shadow, no longer helpful in tracing the outline of this youngest of giant impact features.

Last Quarter is best just before sunrise, making it ideal for a grab-and-go scope view before heading off to work or listening to the dawn chorus of birdsong over coffee.

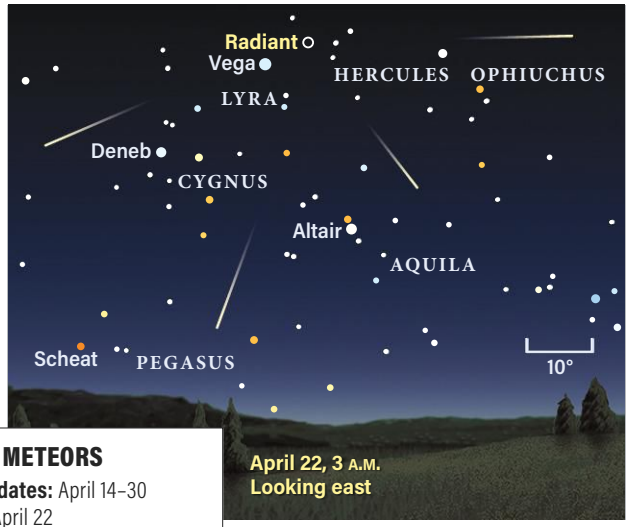
Mare Orientale



Thanks to a favorable libration, we can peer over the western limb of the Moon this month. *CONSOLIDATED LUNAR ATLAS/UA/LPL. INSET: NASA/GSFC/ASU*

METEOR WATCH | Ancient debris

Lyrid meteor shower



The best time to observe the Lyrids is early on the morning of the peak. The Moon rises around 4 A.M. local daylight time.

LYRID METEORS
Active dates: April 14–30
Peak: April 22
Moon at peak: Waning crescent
Maximum rate at peak: 18 meteors/hour

SKIES WILL BE DARK for the annual Lyrid meteors, which are active from April 14 to 30. On the day of the peak, April 22, there's a waning crescent Moon that doesn't rise until nearly 4 A.M. The radiant of the shower, near Vega in Lyra the Lyre, is already 30° high by midnight, offering many hours to catch the fleeting meteors as they skip into Earth's atmosphere and burn up.

An older meteor shower, the Lyrids are associated with the 416-year orbit of Comet C/1861 G1 (Thatcher). Its debris has spread out with time, reducing the hourly rate to modest amounts. The Lyrids are expected to produce about 20 meteors per hour once the radiant is nearly overhead, which occurs in the hour before dawn. Expect lower rates in the earlier-morning hours.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight April 1
11 P.M. April 15
10 P.M. April 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

APRIL 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 The Moon passes 5° north of Uranus, 10 A.M. EDT

2 The Moon passes 6° north of Jupiter, 8 P.M. EDT

Mars passes 4° south of Pollux, 11 P.M. EDT

4 First Quarter Moon occurs at 10:15 P.M. EDT

5 The Moon passes 2° north of Mars, 3 P.M. EDT

6 Mercury is stationary, 2 A.M. EDT

10 Venus is stationary, 11 A.M. EDT

12 Full Moon occurs at 8:22 P.M. EDT

The Moon passes 0.3° south of Spica, 10 P.M. EDT

13 The Moon is at apogee (252,460 miles from Earth), 6:48 P.M. EDT

16 Mercury passes 0.7° south of Neptune, 3 P.M. EDT

Mars is at aphelion (154.9 million miles from the Sun), 6 P.M. EDT

The Moon passes 0.4° south of Antares, 7 P.M. EDT

20 Last Quarter Moon occurs at 9:36 P.M. EDT

21 The Moon passes 0.7° south of Pluto, 2 A.M. EDT

Mercury is at greatest western elongation (27°), 3 P.M. EDT

22 Lyrid meteor shower peaks

24 The Moon passes 2° south of Venus, 9 P.M. EDT

The Moon passes 2° north of Saturn, midnight EDT

25 The Moon passes 1.9° north of Neptune, 6 A.M. EDT

The Moon passes 4° north of Mercury, 9 P.M. EDT

27 Venus is at greatest brilliancy (magnitude –4.8), 6 A.M. EDT

The Moon is at perigee (221,903 miles from Earth), 12:18 P.M. EDT

New Moon occurs at 3:31 P.M. EDT

28 The Moon passes 5° north of Uranus, 10 P.M. EDT

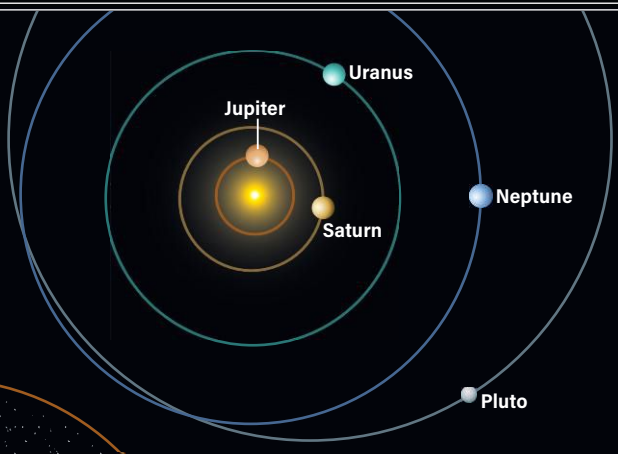
Venus passes 4° north of Saturn, 10 P.M. EDT

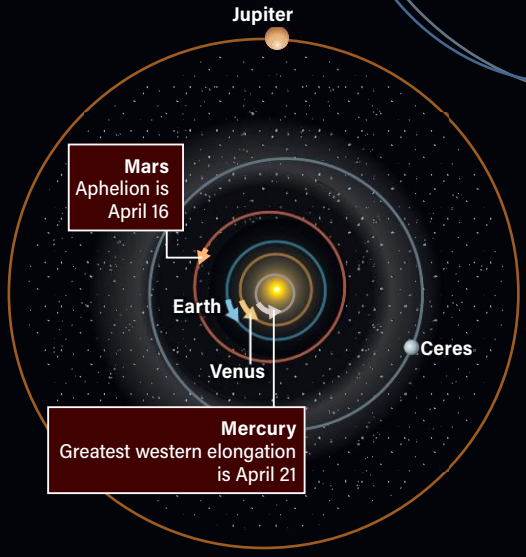
30 The Moon passes 5° north of Jupiter, 2 P.M. EDT

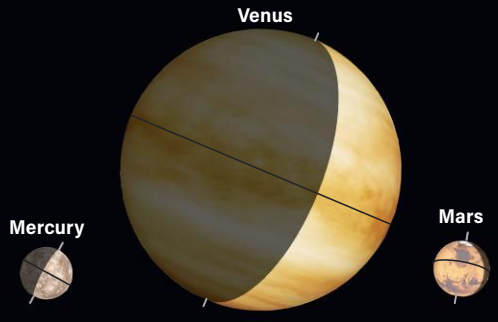
PATHS OF THE PLANETS

THE PLANETS IN THEIR ORBITS

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.



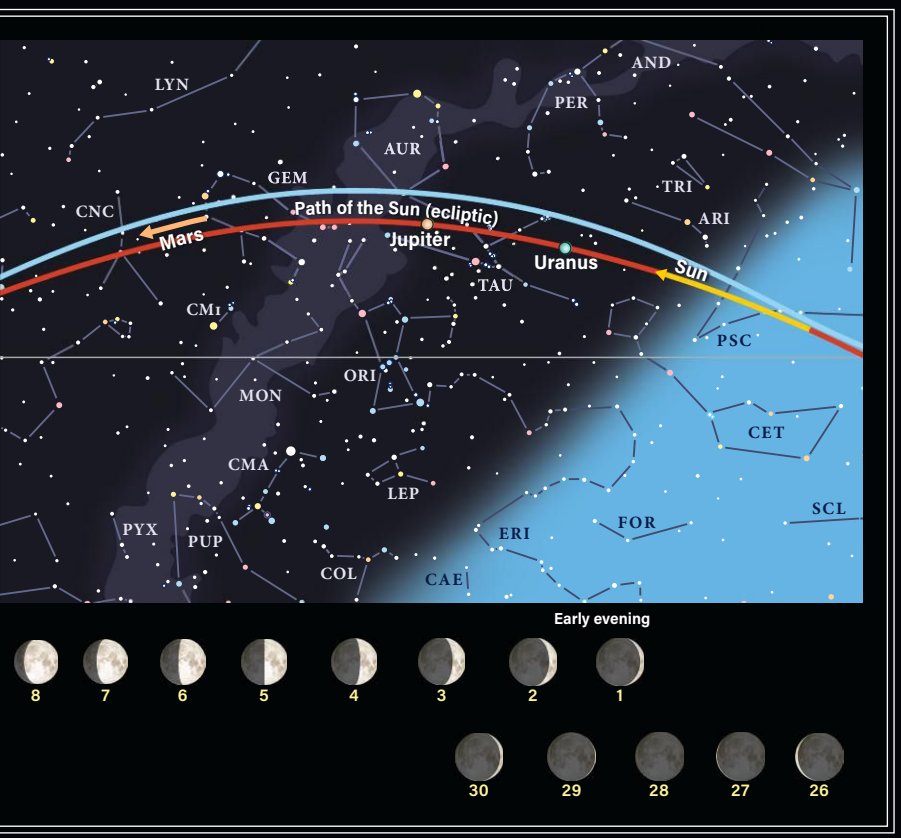




PLANETS	MERCURY	VENUS
Date	April 30	April 30
Magnitude	0.1	–4.7
Angular size	6.9"	37.1"
Illumination	58%	28%
Distance (AU) from Earth	0.977	0.450
Distance (AU) from Sun	0.445	0.725
Right ascension (2000.0)	0h55.4m	23h55.3m
Declination (2000.0)	2°48'	0°52'

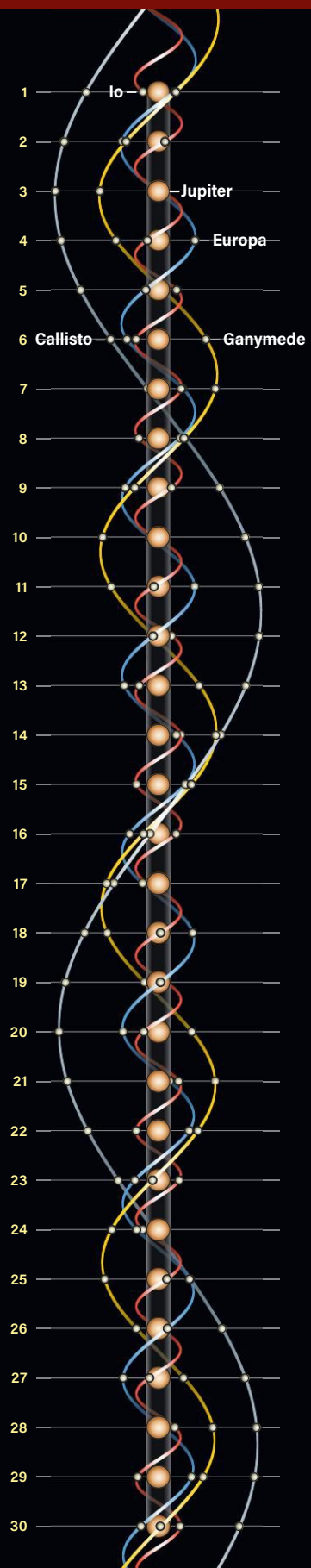
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

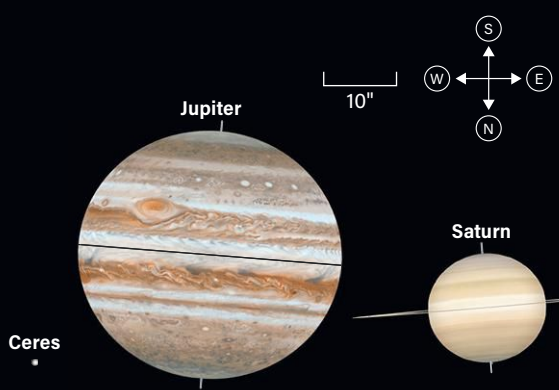
APRIL 2025



JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.





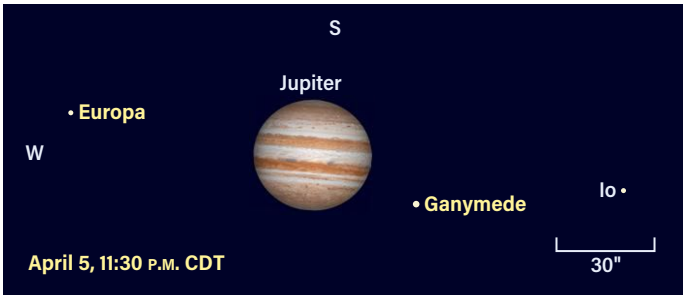
THE PLANETS IN THE SKY

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.

MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
April 15	April 15	April 15	April 15	April 15	April 15	April 15
0.7	9.3	–2.0	1.2	5.8	7.8	15.3
7.4"	0.4"	34.8"	15.9"	3.5"	2.2"	0.1"
90%	99%	99%	100%	100%	100%	100%
1.272	3.725	5.658	10.462	20.396	30.800	35.375
1.666	2.985	5.118	9.599	19.536	29.892	35.242
8h03.9m	23h31.7m	5h07.8m	23h47.6m	3h31.2m	0h02.8m	20h26.2m
22°46'	–12°03'	22°37'	–3°29'	18°49'	–1°05'	–22°48'

 — Continued from page 29

Disappearing act



This chart shows the location of Ganymede just as it is about to start disappearing into Jupiter's long, dark shadow. Callisto lies outside this field of view, farther to the west.

while its shadow appears as a black dot in the center of Jupiter. The shadow exits 66 minutes later.

Europa undergoes a similar sequence the next evening (April 12). As the moon exits the disk around 10:20 P.M. EDT, its shadow has only just begun to transit and doesn't reach the middle of the disk for another 50 minutes. This is because Europa's orbit is larger than Io's. Also notice that Ganymede is approaching the northwestern limb of the planet, setting up an occultation. Ganymede begins to hide behind Jupiter just before 10:10 P.M. MDT. (Note the time zone change, as Jupiter is now very low in the Central time zone.) Europa's shadow exits the disk just under 20 minutes later.

Io transits again on the 18th, followed again the next day by Europa. This time, on the second evening Ganymede is well off the western limb, not reaching occultation before the planet sets.

As April opens, **Mars** stands 70° high in the southern sky in Gemini an hour after sunset. It shines at magnitude 0.4 on the 1st, brighter than either of Gemini's brightest stars, Castor and Pollux. On April 1, you'll find the 4th-magnitude star Kappa (κ) Geminorum less than a Moon's-width north of Mars. By the 10th, Mars stands in line with Castor and Pollux, 5.5° from the latter.

Mars crosses into Cancer on the 12th and its nightly path makes a beeline for M44, the Beehive star cluster. By April 30, Mars stands 2° northwest of the fine cluster, truly a spectacle in binoculars or low-power scope.

Through larger telescopes, Mars remains challenging as it recedes from Earth. It's a tiny 8" in diameter on April 1; martian surface features are hard to spot and it's well past its best. The apparent diameter shrinks to just under 7" by the 30th. Distinctly noticeable is the 90-percent-lit disk.

Mars sets around 3:30 A.M. local daylight time on April 1, and more than an hour earlier by the 30th.

Venus, Mercury, and Saturn reappear in the morning sky. **Venus** is easier to spot due to its brilliance, particularly if you have a clear eastern horizon. On the 1st, it appears low in the east an hour before sunrise. At magnitude –4.2, it's easy to spot soon after rising. By the 15th, Venus is magnitude –4.7 and stands 12° above the horizon at 6 A.M. local daylight time. On the 1st, a telescope shows a slender, 4-percent-lit crescent

WHEN TO VIEW THE PLANETS

EVENING SKY
Mars (southwest)
Jupiter (west)
Uranus (west)

MIDNIGHT
Mars (west)
Jupiter (west)

MORNING SKY
Mercury (east)
Venus (east)
Saturn (east)
Neptune (east)

1:2:4 **Ganymede, Europa, and Io have resonant orbits. For every one orbit of Ganymede around Jupiter, Europa makes two orbits and Io makes four.**

COMET SEARCH | Pushing the power and yourself

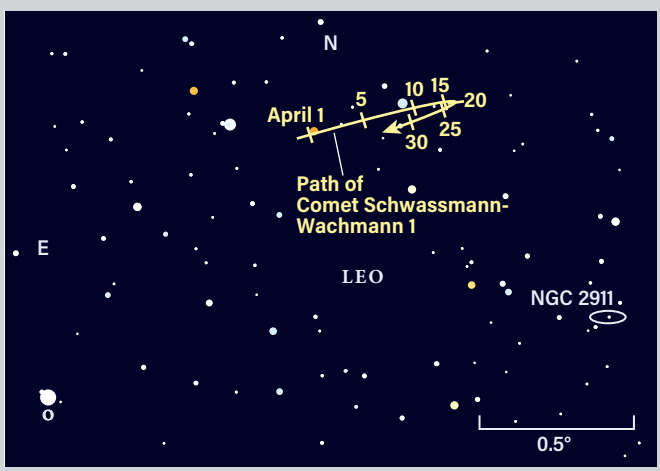
BARRING ANOTHER fast-moving surprise visitor from the Oort Cloud, this year's comet roster is a suite of challenging ones, with one hopeful that goes into outburst regularly. Now's the opportunity to upgrade your high-power deep-sky skillset.

Our target is enigmatic 29P/Schwassmann-Wachmann. Orbiting between Jupiter and Saturn, it's classified as a Centaur. More than once a year, it undergoes mini-explosions to jump to 11th magnitude as expelled dust scatters sunlight back to us, bringing it within range of an 8-inch scope under a dark sky.

First calibrate yourself with galaxy NGC 2911, 1.8° west of Omicron (o) Leonis, itself a bit west of Regulus. At magnitude 11.5 and covering 2', the galaxy makes a great doppelgänger for a fainter comet, including soft edges and increasing brightness into the core. When you go for magnifications above 150x, the field gets unsettlingly dark at first, but stick with it and focus on the 8th- to 9th-magnitude stars nearby. Tap the scope gently to trigger your eyes' peripheral motion reception. Relax, sit down if possible, and use a dark towel over your head to block out stray light.

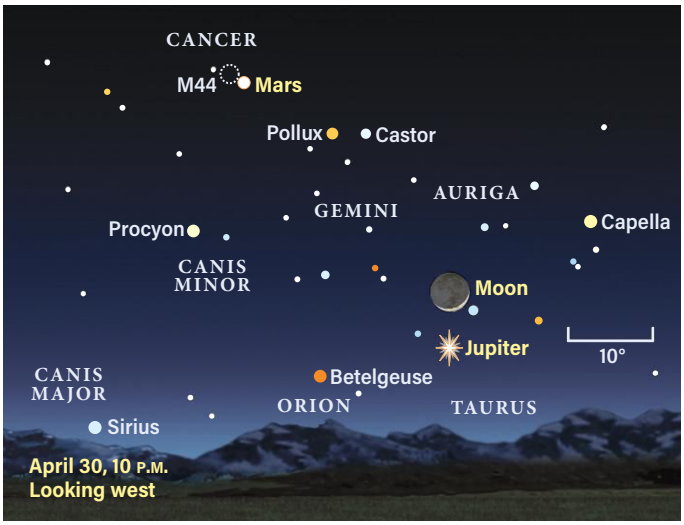
Shift north 1° to a magnitude 7.7 star and use those skills to suss out Schwassmann-Wachmann. You can even try 200x for small objects like these.

Comet 29P/Schwassmann-Wachmann



29P/Schwassmann-Wachmann, also called Schwassmann-Wachmann 1, makes a tight turnaround near Omicron Leo this month.

Approaching the hive



By the end of April, Mars is just 2° northwest of M44, the Beehive Cluster.

spanning 57". A week later, it's 52" wide and 8 percent lit.

Venus' appearance in a telescope continues to change quickly as the planet's separation from the Sun increases. On the 15th, the disk spans 47" and is 15 percent lit. By April 30th, the phase has expanded to 28 percent lit and the disk has shrunk further to 37", due to its increasing distance from Earth.

Mercury begins the month shining dimly but brightens as it approaches its April 21 western elongation. One challenging opportunity occurs the morning of April 12, when Mercury and **Saturn** stand side by side, with 2.2° separating them. They are about 7° below Venus, which acts as a bright signpost to find the much dimmer pair. Mercury is magnitude 0.9 and Saturn shines at magnitude 1.2, both difficult in advancing twilight. The pair rises around 5:30 A.M. local daylight time and sunrise is less than an hour later, so a very clear and transparent sky with a clear eastern horizon is needed to spot the planets.

Mercury brightens to magnitude 0.4 by the 21st, when it rises nearly an hour before the Sun. During the last week of April, Mercury continues brightening, although its angular separation from the Sun is now declining. It achieves magnitude 0.1 on the 30th, and by 6 A.M. local daylight time stands 9° above the eastern horizon.

Saturn is a dim 1st-magnitude object in morning twilight. The ringed planet rises at 5 A.M. local daylight time in late April and stands nearly 5° above the horizon by 5:30 A.M. for mid-latitudes (40° north). A waning crescent Moon hangs within a few degrees of the planet on April 24 and 25. Saturn passes 4° due south of Venus on the 28th.

Telescopic views of Saturn, while tricky in the oncoming twilight, are worthwhile to glimpse the very fine shadow of the rings on the 16"-wide disk. Following the ring-plane crossing in March, we are now looking up at the southern face of the rings, but the Sun still illuminates the northern side until the first week of May. Our view of the backlit ring system offers a unique sight for a short time, worthy of an early-morning excursion.

Neptune is still close to the Sun and not visible early in the month. By the end of April, the magnitude 5.8 ice giant is 5° high in the east an hour before sunrise, very challenging to view.

European observers experience a lunar occultation of the Pleiades on April 1/2. The 3.5-day-old crescent Moon crosses the many stars in the cluster over a roughly two-hour period. A small telescope (60 to 90 mm) or even binoculars will show many of the brighter stars undergoing occultation, disappearing behind the dark limb of the Moon. Many 7th- and 8th-magnitude stars are occulted as well, observable in larger telescopes.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

LOCATING ASTEROIDS
Photobombing the Leo Triplet

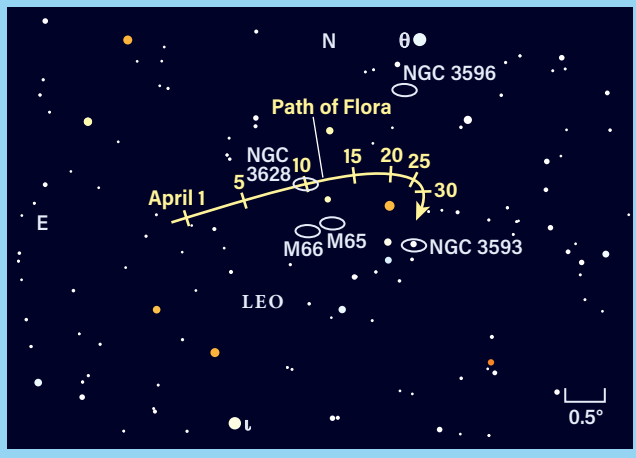
HERE'S SOME FUN for both visual observers and imagers: Main-belt object 8 Flora is passing in front of a most popular deep-sky field.

From the suburbs, a 6-inch scope will readily show the 10th-magnitude dot in the sparse star field. By making a sketch with three or four dots and returning on another night, you can see it shift position. Although galaxies struggle in light pollution, M65 and M66 have decently bright cores that can rise to visibility for patient observers. The key here is to forget the images that show expansive halos and simply look for a very small, fuzzy "star." Try powers above 120x and take your time.

Imagers love revealing the long dust lane of the edge-on galaxy NGC 3628 just to the north of M65 and M66. Flora will be very close to tracking down this dark channel over the course of four nights, from the 8th to the 11th. A two-hour session generates a 20"-long streak. The nearby Moon will lighten the background considerably.

Flora was picked up visually by John Hind in 1847 as an interloper not shown on his star charts. In our lifetime, it has been measured to be just out of round and 90 miles across.

The Lion's haunches



Also in Leo this month, Flora is located near the Lion's back end, with several galaxies nearby.

Once thought a block of worthless ice, this continent plays a key role in stabilizing Earth's climate. BY CHRIS RAPLEY

DON'T MESS WITH ANTARCTICA

In January 1774, Captain James Cook's third and final attempt to sail south in search of the elusive *Terra Australis* was blocked by impenetrable sea ice. A frustrated Cook left the question of a southern land mass unanswered and later wrote, "If any one should have resolution and perseverance to clear up this point by proceeding farther than I have done, I shall not envy him the honour of the discovery; but I will be bold to say, that the world will not be benefited by it," in a journal entry.

Despite Cook's belief that *Terra Australis* wouldn't serve any purpose to humanity, explorers did not yield. Half a century later, Russian naval officer Fabian von Bellingshausen and British Royal Navy officer Edward Bransfield independently made the first recorded sightings of the continent in January 1820. And in the early 20th century, three legendary figures — Irish explorer Ernest Shackleton,

A single person appears tiny compared to numerous icebergs and a wall of Antarctic mountains. Although one human seems like a minor intrusion, collectively we are causing damage to this majestic frozen tundra. CHRIS RAPLEY

British Royal Navy officer Robert Falcon Scott, and Norwegian explorer Roald Amundsen — finally embarked on perilous missions to conquer the last great frontier.

Those earliest explorers did much in their first forays. They charted sizable areas of the frozen wilderness, took systematic meteorological observations, made significant contributions to the understanding of glaciers and ice sheets, revealed the unique adaptations of the indigenous marine species, discovered the southern magnetic pole, and finally reached the South Pole itself. One of the most astonishing discoveries was evidence from fossils that Antarctica had once been part of the ancient supercontinent Gondwana — a warm and ice-free terrain, teeming with life.

The explorers' journeys not only pushed the boundaries of human endurance, but reaffirmed the icy continent's unforgiving nature, and its apparent dearth of opportunities for exploitation, just as Cook had predicted. What they didn't know was that Antarctica is in fact incredibly valuable — as a cornerstone of Earth's climate.

Recognizing Antarctic tundra

Antarctica remained largely overlooked for another half-century, until it once again became of interest during the International Geophysical Year (IGY), from July 1957 to December 1958. The establishment of research stations in Antarctica and first crossing of the continent by the Commonwealth Trans-Antarctic Expedition (TAE) captured public attention.

I recall being fascinated by the accounts of the TAE's derring-do and the dramatic images of the difficulties they encountered (see page 42) at a young age. I also remember my 1956 *Oxford School Atlas*' Antarctic map, accompanied by the text: "Most of this Continent is completely unknown and unexplored," reinforcing its status as a

zone of mystery and inspiring me to pursue the research of climate science.

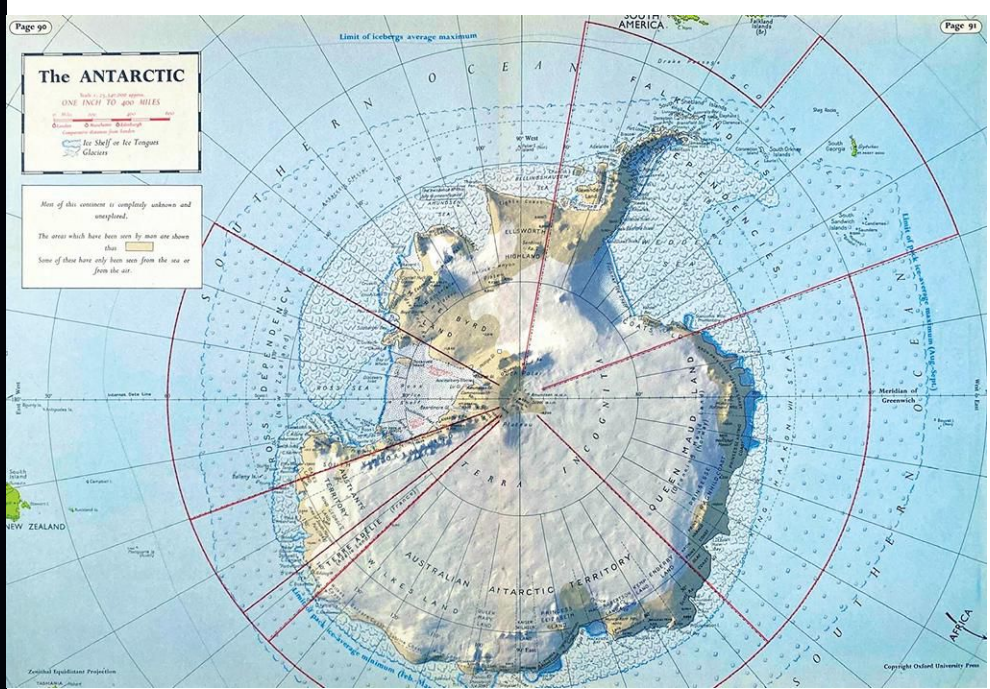
What I was unaware of at the time were the enormous strides in scientific knowledge and understanding being harvested. These included extensive surveying and mapping, such as seismic and radar studies, glaciology, ice core drilling, atmospheric research, and oceanography. Antarctica was shown to be a single continent with a dynamic and mobile ice sheet cover much thicker than previously thought, reaching depths up to 15,000 feet (4,800 meters)! The continent and Southern Ocean emerged as key components of the global climate system — particularly their influence on the atmospheric circulation, ocean currents, and sea levels.

The data gathered during the IGY laid the foundation for the wide-ranging studies that followed, and marked the beginning of Antarctica's transformation into a vital platform for global scientific research. IGY also demonstrated the effectiveness of international scientific collaboration and promoted science as a diplomatic tool, which was of great importance during the Cold War era. One of IGY's most enduring legacies was the establishment of the Antarctic Treaty in 1959, which designated Antarctica as a continent for peaceful scientific exploration. The Antarctic Treaty Parties govern Antarctica and the region below 60° south latitude, coordinate international research activities in the region, and provide scientific advice to guide legislation.

In the seven decades since the IGY, Antarctic research has grown into a major multinational endeavor, despite the costs and complexities of operating with long supply chains in such a vast, hazardous, and challenging environment. The number of research stations has increased from 19 to about 70, with approximately 30 operating year-round. During the Antarctic summer (from October to March), conditions are more favorable, accessibility is easier, and the population of scientists and support staff — supported by about 30 nations — can exceed 4,000. This number drops to less than 1,000 during the winter months, when conditions are severe and only essential staff remain.

Additionally, for about the past 40 years, the region has been probed by an ever-expanding fleet of orbiting satellites, carrying sophisticated gravimeters, high-resolution optical and radar imaging instruments, altimeters, and passive microwave sensors. They map the gravity, topography, and dynamic behavior of the ice sheet and its surrounding floating ice shelves, as well as sea ice cover and oceanic behavior. The view from space is powerful, since it can achieve

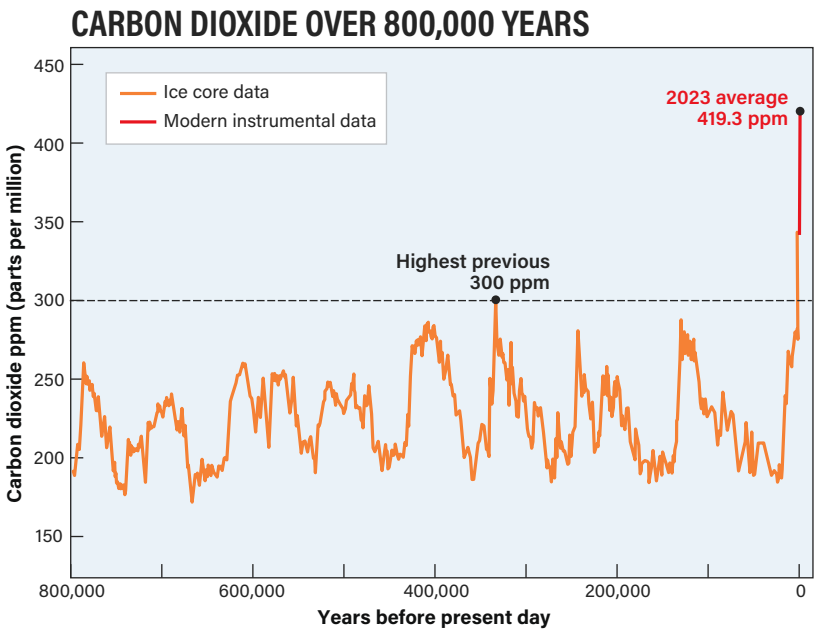
Captain James Cook is superimposed on the HMS *Resolution* and HMS *Adventure* ships used during his failed 1774 attempt to discover *Terra Australis* — the continent we now call Antarctica.
BRITISH ONLINE ARCHIVES


Page 90
The ANTARCTIC
Ice Shelf or Ice Tongues
Glaciers
Most of this continent is completely unknown and unexplored.
The areas which have been seen by man are shown thus
Some of these have only been seen from the sea or from the air.
Limit of icebergs average maximum
Page 91
SOUTH AMERICA
OCEAN
SOUTHERN
Meridian of Greenwich
NEW ZEALAND
AUSTRALIAN ANTARCTIC TERRITORY
Copyright Oxford University Press

"Most of this Continent is completely unknown and unexplored," notes this map of Antarctica from the 1956 *Oxford School Atlas*.
OXFORD SCHOOL ATLAS

Thick layers of snow and ice break apart and create deep crevasses. The weight of the top removes the air and creates dense crystals, making a glacier's fissures glow in blue. CHRIS RAPLEY

Records from the European Project for Ice Coring in Antarctica show that atmospheric carbon dioxide (CO_2) concentrations have been more or less stable over the last 800,000 years — until now, with a massive rise in CO_2 levels due to human activity. *ASTRONOMY:* ROEN KELLY, AFTER NOAA CLIMATE.GOV



a spatial and temporal coverage unachievable from the ground or even from aircraft and balloons. Microwave sensors are unaffected by clouds or daylight, operating in all weather and through the long polar night.

Why study Antarctica?

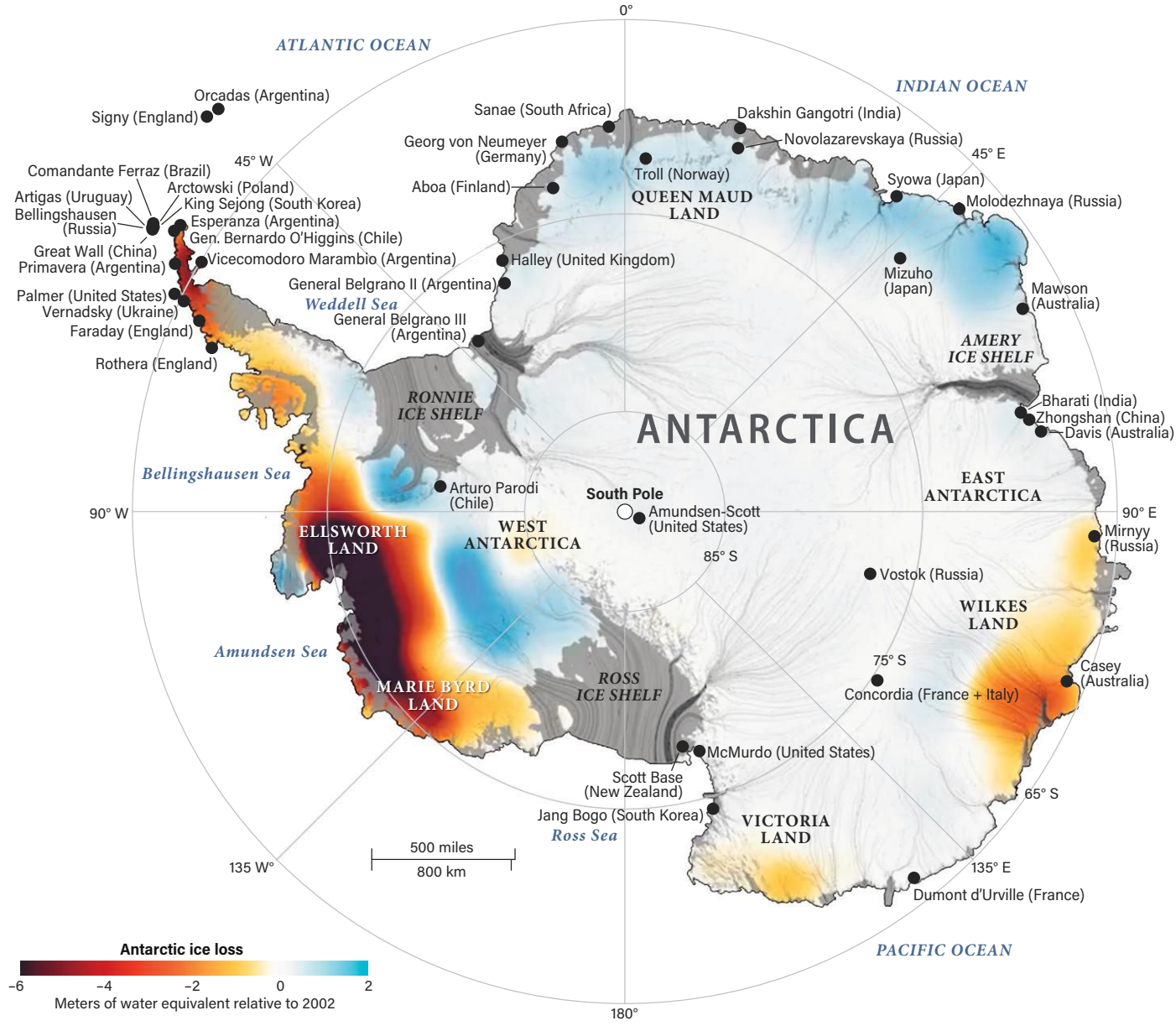
My interest in the southernmost continent catalyzed in 1982, when I was asked to lead a study for the European Space Agency (ESA) on the use of spaceborne radar altimeters to study polar ice. Since then, I've realized that there are four main reasons why Antarctica is of deep scientific interest.

First, studies of Antarctica have made significant contributions to our understanding of Earth's geological history — particularly regarding tectonic movements, the supercontinent cycle, and crucial mass extinction events like that marked by the Cretaceous-Paleogene (K-Pg; formerly known as K-T) boundary.

Second, Antarctica's extreme and isolated conditions offer a unique environment for studying evolutionary adaptations. Investigating the specialized metabolic pathways and enzymes developed by Antarctic microbes to survive subzero temperatures contributes to research on biochemical survival mechanisms. For example, organisms like the extremophiles that thrive in freezing temperatures and at high salinity help us better understand life on Earth and provide insights for astrobiologists.

Third, Antarctica is an excellent place to find meteorites — more than 60 percent of the current research collections originate from there. After falling onto the ice sheet, these space rocks can be preserved for thousands or even millions of years. As the ice flows toward the continent's edges, it transports them and ultimately creates areas where meteorites are concentrated, trapped by the landscape. When the ice sublimates or is eroded

ANTARCTIC ICE LOSS AND GAIN



This Antarctic map shows the amount of ice loss (orange/red) or ice gain (blue) between 2002 and 2020. Operating stations established by several countries are also shown. *ASTRONOMY*: ROEN KELLY, AFTER NASA/ENCYCLOPÆDIA BRITANNICA, INC.

by wind, it exposes specimens on the surface, making them easy to spot. These meteorites often contain ancient materials that predate Earth, providing clues to how the planets formed and the conditions of the nebula that created the solar system.

Last, due to its location near Earth's magnetic South Pole, Antarctica provides an ideal platform for studying the ionosphere and magnetosphere, with the goal of understanding how solar winds and charged particles interact with the magnetic field. Solar storms and geomagnetic activity can disrupt power grids, communication systems, and GPS services. The region's isolation from human-made interference, combined with the long polar nights, offer a clear and stable environment for long-term studies of both the polar atmosphere and space weather.

Global impacts

Decades of study have demonstrated that Antarctica holds a treasure trove of scientific knowledge, contradicting Captain Cook's gloomy prediction — a poignant irony for an individual who dedicated his life to exploration and expanding the limits of human knowledge. However, it is in the field of climatology where Antarctica truly stands out — and where its role, significance, and value become fully apparent.

The Antarctic ice sheet and the

surrounding ice-covered ocean are vital parts of Earth's climate system, influencing its atmosphere, ocean, land, ice, and biological processes. The bright surface of the ice reflects a large amount of solar radiation, resulting in both local and global cooling. The continent's cold temperatures also maintain a strong polar vortex, which stabilizes the jet stream and keeps cold polar air from spreading to midlatitudes.

During the summer, Antarctic sea ice is limited to coastal areas, but in winter, it expands dramatically, reaching as far north as 60° south or beyond. Sea ice acts as an insulator, preventing the exchange of heat, moisture, and momentum between the ocean and atmosphere.

Antarctic bottom water, which forms under sea ice and beneath ice shelves, is one of the densest water masses on the planet. It drives global ocean circulation and interacts with some 40 percent of the world's ocean — extending to around 50° north in the Atlantic Ocean. Cold, nutrient-rich surface waters in the Southern Ocean support phytoplankton, which take in carbon dioxide and play a role in sequestering carbon in the deep ocean.

The Antarctic ice sheet itself holds about 60 percent of the world's freshwater. If it were to melt, global sea levels would rise by nearly 200 feet (58 m), devastating coastal communities worldwide. The floating ice shelves around its periphery help stabilize the ice sheet, modulating its contribution to sea level rise.

Through these avenues of influence, Antarctica acts as Earth's "air conditioner," stabilizing global temperatures through its reflective ice, cold ocean currents, and impact on atmospheric circulation. These processes help moderate global warming and maintain climate balance globally, making Antarctica a keystone of Earth's climate system.

So, what can our global air conditioner tell us about the state of that climate system?

Snow layers compact into ice over time, trapping air bubbles that preserve samples of past atmospheres. By drilling deep into the ice and then analyzing the chemical and isotopic content of the extracted cores, scientists can track historical temperature changes and greenhouse gas concentrations. This research has revealed a close link between temperature, greenhouse gas levels, and ice sheet changes, all driven by astronomical cycles, marking one of the most significant geophysical discoveries of our time.

An ice core (right) is a long cylinder extracted from layers of snow built up over the course of several years. A cross-section slice (above) of an ice core shows countless trapped air bubbles, which reveal information about past atmospheric conditions. R.MULVANEY/BAS; REUTERS/LAURENT AUGUSTIN/CNRS/LABORATOIRE DE GLACIOLOGIE ET GEOPHYSIQUE DE L'ENVIRONMENT (LGGE)/HANDOUT (2)

A key finding is that carbon dioxide levels in the atmosphere have never exceeded 300 parts per million (ppm; meaning the number of carbon dioxide molecules per million molecules of dry air) during the last 800,000 years. Today, carbon dioxide levels are at 427 ppm (see page 39), primarily as a result of burning fossil fuels. This is critical evidence that human activities have clearly altered the chemistry and physics of the atmosphere. In doing so we have upset the planetary energy balance, which in turn is driving global climate change as well as having impacts on Antarctica.

Are we the bad guys?

In 1978, the American glaciologist John H. Mercer described how, in a warming world, we could expect a successive collapse of ice shelves extending southward along the Antarctic Peninsula. He further warned this could be followed

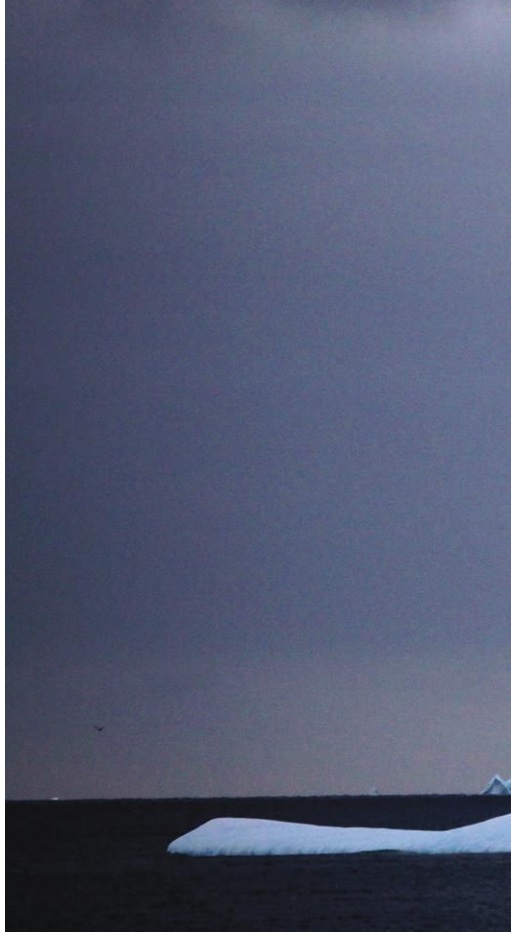
COSTLY UPKEEP

ANTARCTICA ALSO PLAYED A HISTORIC ROLE in the discovery of the hole in the ozone layer. In 1985, British Antarctic Survey scientists reported a severe depletion of the ozone over the Halley Research Station, which was subsequently confirmed by satellite measurements. It was attributed to the widespread use of chlorofluorocarbons (CFCs) in aerosol sprays, refrigerants, and solvents. The unique meteorological conditions in Antarctica, including the formation of polar stratospheric clouds during the long, cold winter, promote chemical reactions that release chlorine atoms from CFCs. These chlorine atoms then destroy ozone molecules, leading to the seasonal thinning of the ozone layer.

The discovery of the ozone hole spurred international action, leading to the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987. This landmark agreement committed countries to phasing out the production and use of ozone-depleting substances, particularly CFCs. The protocol has been highly successful, with global CFC emissions drastically reduced. The ozone layer has since shown signs of recovery, with the Antarctic ozone hole projected to return to pre-1980 levels by the middle of the 21st century. — *C.R.*

ALEXANDR MAKAROV/DREAMSTIME.COM

This Commonwealth Trans Antarctic Expedition motorized vehicle, called the Tucker Sno-Cat, is stuck in a tight spot, hovering over an ominous crevasse as team members try to find a solution in a 1957 snapshot. Sno-Cats are used to haul supplies, tow sledges, and transport personnel. THE CROSSING OF ANTARCTICA (THAMES & HUDSON)/GEORGE LOWE, HUW LEWIS JONES



by accelerating ice loss in West Antarctica. Airborne radio-echo sounding surveys, which penetrate the ice to its base, have revealed that the West Antarctic Ice Sheet (WAIS) is particularly vulnerable to melting because it rests on bedrock below sea level. Salt lowers the freezing point of water, which makes the ice underwater more prone to disappearing.

Satellite and in situ data have indeed shown such successive collapse of Peninsula ice shelves and an accelerating loss of ice from the WAIS (see page 40). The latter is estimated to account for about 0.02 inch (0.4 millimeter) of the current 0.2-inch (4 mm) annual mean global sea level rise. If the WAIS was to be drained, it would cause the global sea level to rise about 10 feet (3 m).

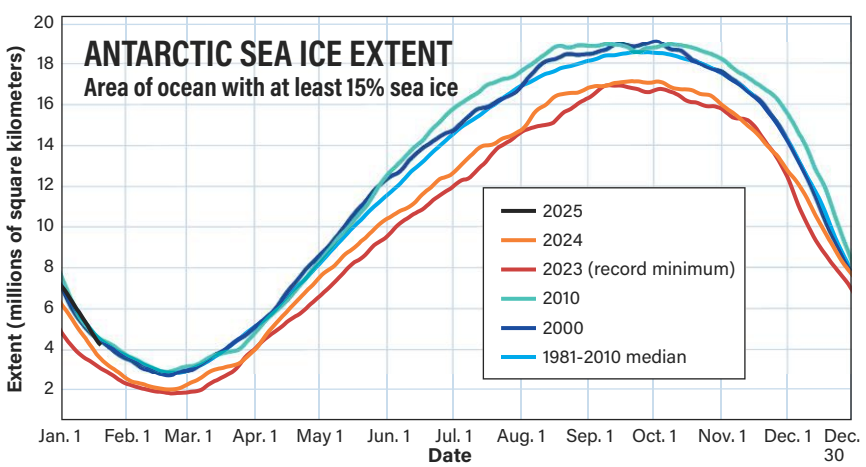
While the seasonal extent of Antarctic sea ice had remained relatively stable or even increased slightly over the last 40 years, recent data show significant changes. Specifically, since 2016, the extent of the ice has experienced record low levels during several consecutive seasons.

The messages from collapsing Antarctic ice leaves much uncertainty about its future behavior. Both the WAIS ice flow and the Southern Ocean ice cover are potential Earth system tipping points — critical thresholds within Earth's climate for collapse which, once triggered, cannot be stopped or reversed. Such complex systems are hard to model, and they have the capacity for surprises. Even so, there is a strong likelihood that the climate system we are creating will be significantly less amenable to human wellbeing than the one we inherited.

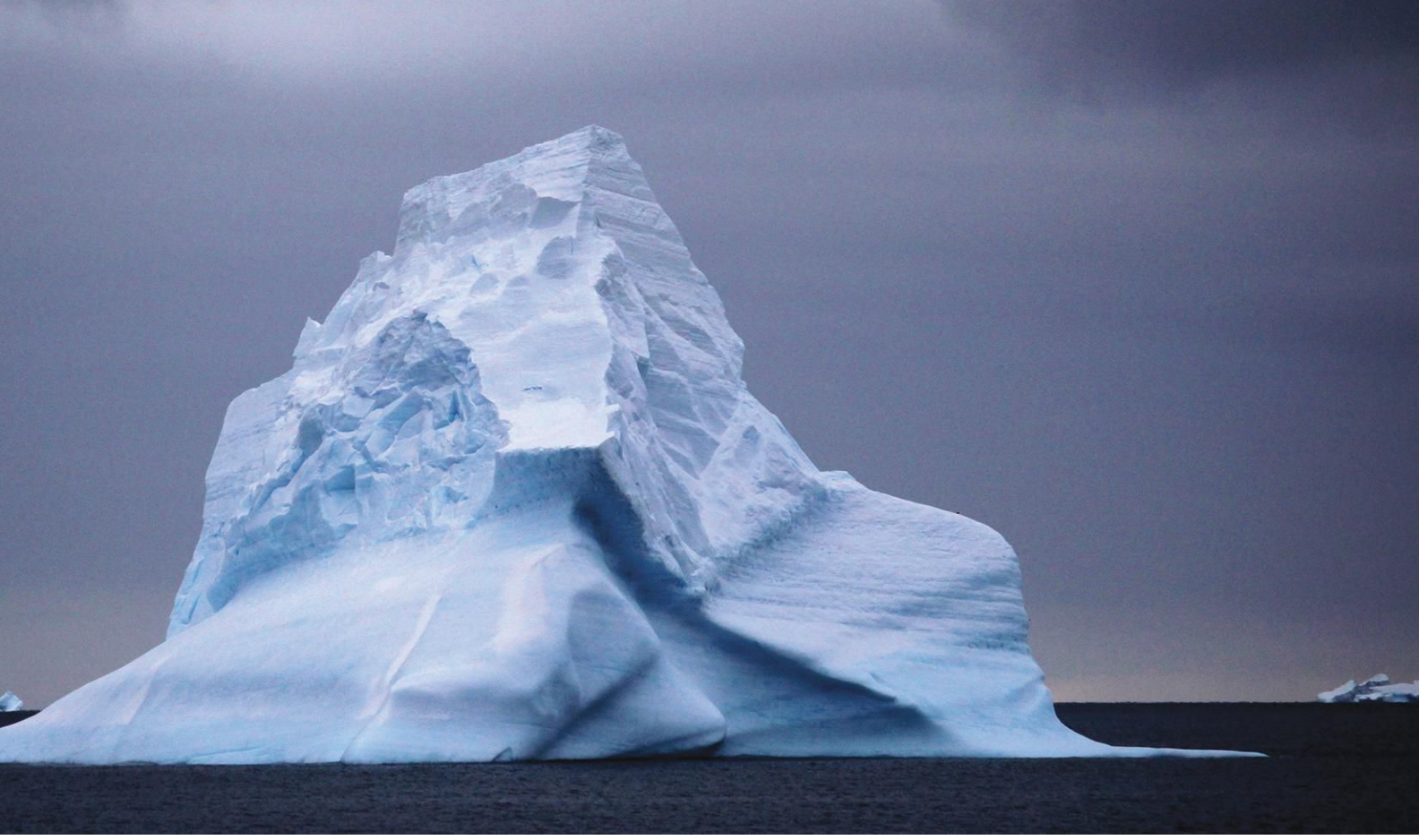
Have we inadvertently launched Antarctica on a path that could ultimately return it to a state of warmth, devoid of ice? UN Secretary General António Guterres characterizes our predicament as an alarming "code red."

Now's our chance to step up

So, how can these alarming signals from the Antarctic be turned into meaningful action? Tackling climate change requires a dual approach: reducing the magnitude and severity of change, whilst adapting to its ineluctable consequences. The top priority is to cut greenhouse gas emissions by transitioning to renewable energy, improving energy efficiency, halting deforestation, restoring ecosystems, and adopting sustainable agriculture.



A dramatic reduction in the extent of Antarctic sea ice occurred during 2023, as compared with several previous decades.
ASTRONOMY: ROEN KELLY, AFTER NATIONAL SNOW AND ICE DATA CENTER



▲ A pristine iceberg laced with dazzling streaks of blue presents a stark contrast against the cold, deep black of the sea. CHRIS RAPLEY

◀ One of the many animals that have adapted to the harsh environment of the Antarctic is the graceful albatross. CHRIS RAPLEY

Simultaneously, adaptation involves building resilience through measures such as climate-toughened infrastructure, safeguarding vulnerable communities, enhancing water and food security, and investing in early-warning systems for extreme weather events. However, progress is hindered by the inertia of our modern systems and powerful forces resisting change. Traditional approaches, such as the slow and laborious UN Climate Change Conferences, are proving insufficient.

Nonetheless, strong narratives and examples of success are emerging as robust tools to shift behaviors. Motivated citizens and institutions — such as businesses, cities, regions, and even ad hoc national coalitions — are stepping up to drive transformative change and accelerate the momentum toward a sustainable future.

How does Antarctica fit into this potential equation? To the average world citizen, busy with their daily lives, the realm of the Antarctic seems distant, exotic, and disconnected. Even a senior minister I recently briefed admitted that he had been ignorant of its location; he pointed out that on his children's globe, Antarctica was covered by the manufacturer's label. This detachment underscores the challenge of making Antarctica's key role in Earth's climate system resonate with the global public.

Yet, one possibility is emerging — and from an unlikely quarter. In recent years, Antarctic tourism has seen significant growth. The number of tourists visiting the continent has increased dramatically, rising in three decades from just over 5,000 visitors per season to more than 100,000. This surge reflects a growing global interest in the unique environment of Antarctica. Further, because it is a costly destination, many of these visitors — who naturally require the means to travel there — may be influential. Perhaps their experience of its majesty and fragility will increasingly permeate global awareness, catalyzing humanity to accelerate the scale and pace of actions to both moderate our influence on and adapt to our changing climate system.

For my own part, having visited the frozen continent many times, my abiding memory is of an albatross, effortlessly skimming the ocean waves as it rode the slipstream of a cruising research vessel — perfectly adapted to this harsh and unforgiving domain. It would be a tragedy of cosmic proportions if such perfection were to be lost through our negligence.

Chris Rapley *is a professor of climate science at University College London. He fell in love with Antarctica after leading a study for ESA on polar ice.*

STUDYING OURSELVES

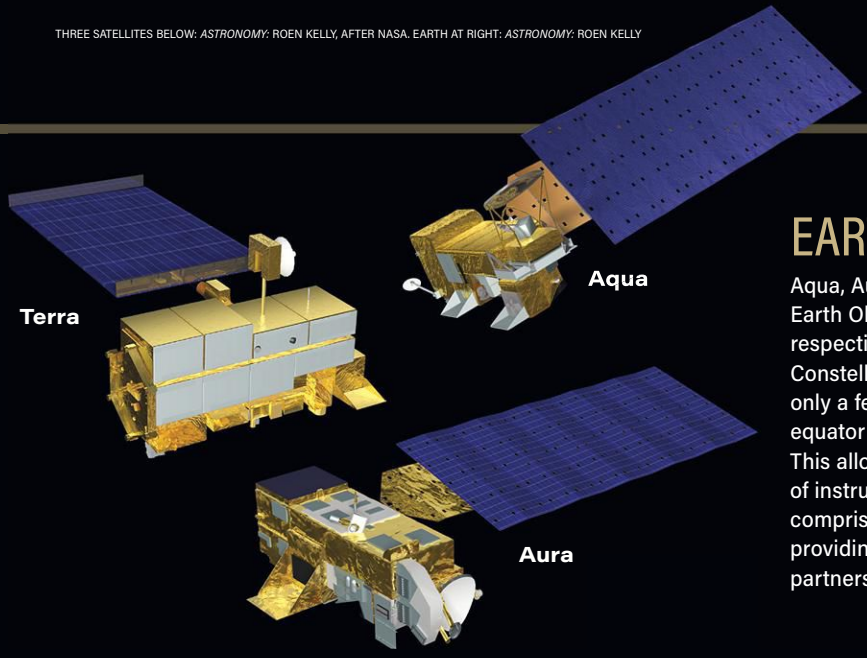
Here's a sampling of some of the satellites that take a look at our planet.

BY KOREY HAYNES

***ASTRONOMY* MAGAZINE TENDS TO FOCUS** on space observatories that peer beyond Earth, into the depths of space. But the vast majority of observational satellites around our blue world stare right back at us.

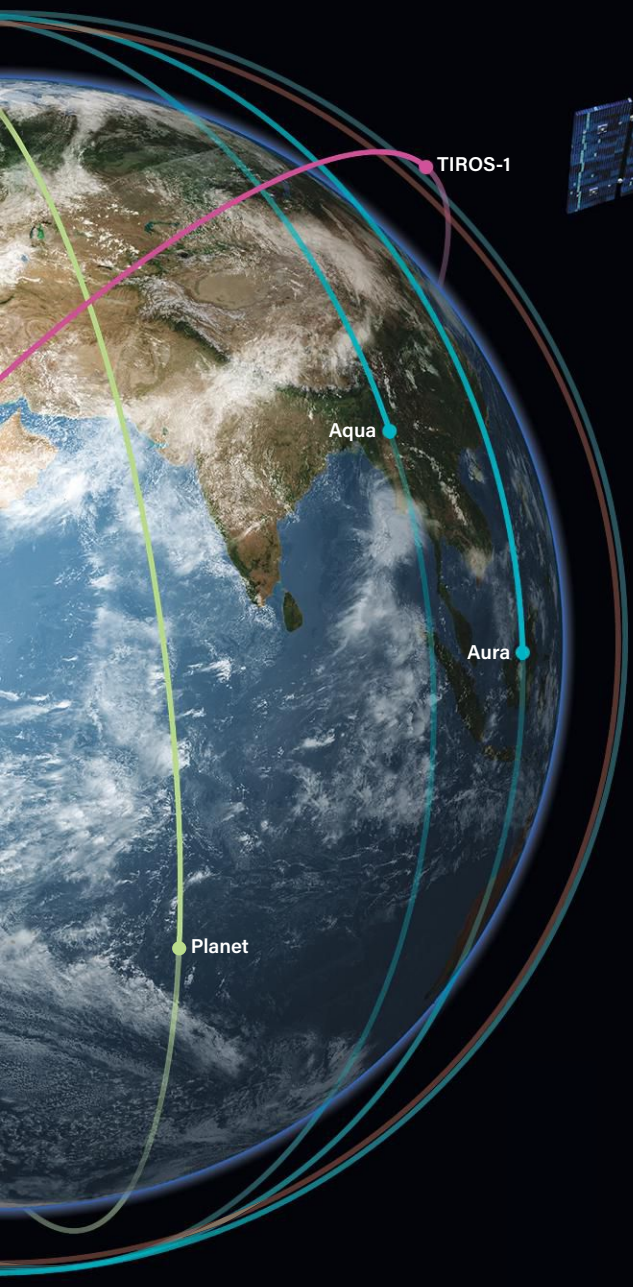
From weather to climate to ocean currents to vegetation, all kinds of Earth-sensing satellites surround our planet, giving a bird's-eye view of our little blue marble. The United States Geological Survey lists 693 Earth-sensing satellites in their database (including retired missions). They work solo or in teams, across many different orbits, observing in visible, radio, and infrared wavelengths, and using radar and lasers. We can't cover them all, but here's a sampling that help us understand this wonderful world we call home.

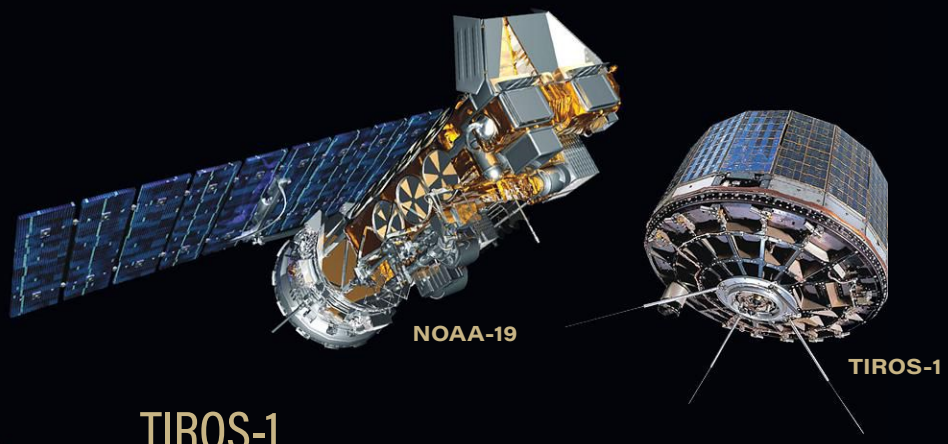
THREE SATELLITES BELOW: *ASTRONOMY:* ROEN KELLY, AFTER NASA. EARTH AT RIGHT: *ASTRONOMY:* ROEN KELLY



EARTH OBSERVING SYSTEM

Aqua, Aura, and Terra are the main spacecraft making up NASA's Earth Observing System, observing the water cycle, air, and land, respectively. Aqua and Aura were also part of the Afternoon Constellation, or A-Train, a group of NASA satellites that flew only a few minutes apart on their polar orbit, crossing the equator in quick succession at 1:30 P.M. local time each day. This allowed the fleet to observe Earth with an enormous array of instruments from several different satellites (the A-Train comprised six satellites in its prime, currently down to three), providing a wealth of constantly updated data to NASA and its partners.





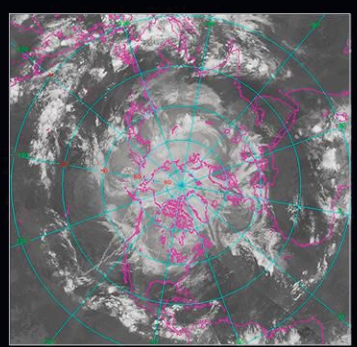
NOAA-19SATELLITE: NASA. TIROS-1 SATELLITE: NASA

TIROS-1

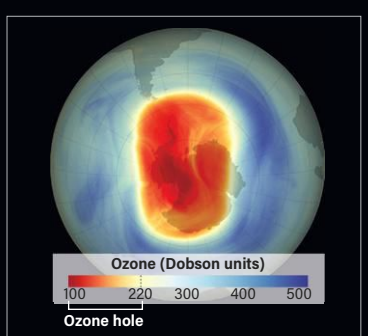
The first weather satellite, TIROS-1 (Television Infrared Observation Satellite) set the stage for generations of science to come. With one launch, the field of meteorology — and many others — changed forever. At the time of launch, scientists weren't sure if weather observations from space would be useful — TIROS was breaking new ground. Even though its images were black and white, grainy, and quaint by modern standards, TIROS-1 provided satellite television views of cloud formations from above for the first time, allowing weather forecasting, hurricane preparedness, crop management, defense planning, and more. It launched in April 1960 and operated for just 78 days. But it succeeded wildly and has had a rich legacy of successful successors.

By 1962, the TIROS program was collecting data continuously, and a long line of satellites, jointly run by NASA and the National Oceanic and Atmospheric Administration (NOAA), continued the mission. The last satellite in the series is NOAA-19, launched in 2009; along with siblings NOAA-15 and -18, it is still in operation today. It is being succeeded by the Joint Polar Satellite System, whose first satellite launched in 2011. The new fleet is taking up TIROS' mantle of providing high-quality data for weather and climate science.

This is the first image taken of Earth by a weather satellite: TIROS-1 captured it April 1, 1960. NASA

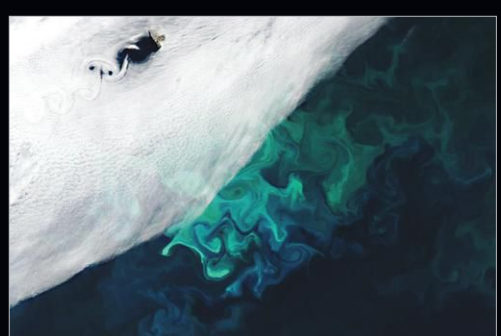


This mapped mosaic image was taken by the NOAA-18 satellite, which has a polar orbit. NOAA



NASA's Aura satellite captured an image of an ozone hole above Antarctica on Sept. 21, 2023. NASA EARTH OBSERVATORY

Images from Terra show ships backed up outside the ports of Los Angeles and Long Beach during pandemic-related supply chain crunches in October 2021. NASA EARTH OBSERVATORY

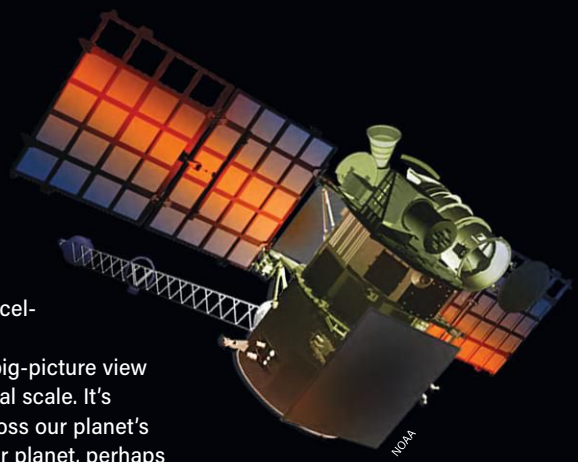


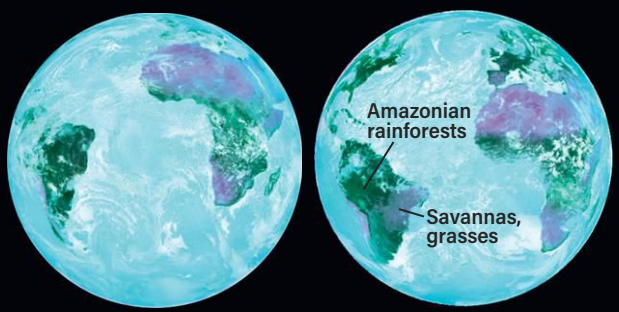
The Aqua satellite captured this image of the swirling tendrils of a phytoplankton bloom off the coast of Svalbard on July 13, 2023. NASA

DSCOVR

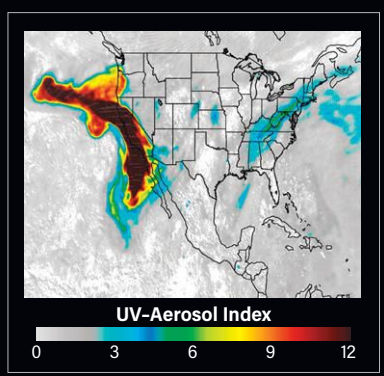
DSCOVR's (Deep Space Climate Observatory) gorgeous full-disk images of our planet make it a shoo-in for this collection. It flies much father into space than anything else featured here, all the way out to the L1 Lagrange point, directly between Earth and the Sun. There, it tastes the solar wind and warns Earth in the event of a geomagnetic storm. And its Earth Polychromatic Imaging Camera, or EPIC, takes pictures of our planet in 10 infrared, visible, and ultraviolet bands every two hours. Because of its position between the Sun and Earth, it always views our planet's dayside, making it an excellent observer of clouds, vegetation, ozone levels, and aerosols.

While it doesn't provide the granularity of the weather satellites in low Earth orbit, its big-picture view allows scientists to study our planet as a whole and observe trends in real time on a global scale. It's imaged the Moon photobombing Earth and recorded the shadow of the Moon racing across our planet's face during a solar eclipse. And it provides a constantly updated "blue marble" view of our planet, perhaps reminding us that while there are many planets out there, only one has ever earned the name "Mother."

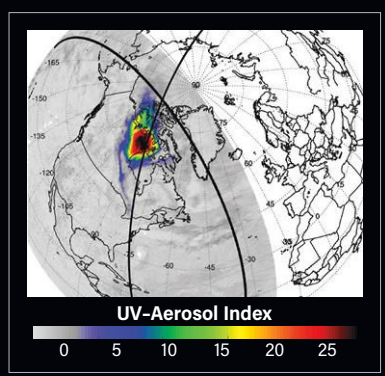




These two images, captured by the DSCOVR satellite, show the changes in green-grass growth in the Amazon during two seasons. The left photo was taken during the dry season and the right in the wet season. NASA



This DSCOVR image shows dense smoke from West Coast fires starting to blow eastward across the U.S. NASA

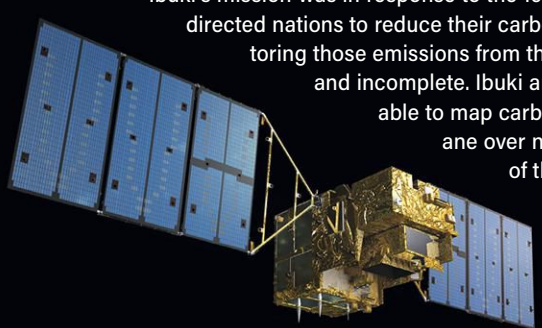


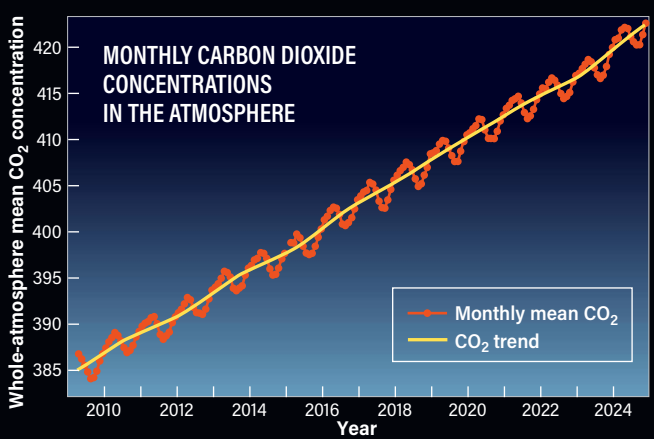
DSCOVR captured this image of a massive smoke plume from the boreal fires in British Colombia in August 2017. NASA

IBUKI

Ibuki ("breath" in Japanese, also known as the Greenhouse Gases Observing Satellite, or GOSAT) was the first satellite designed specifically to study greenhouse emissions from space. The second version, Ibuki 2, launched in 2018 and is still in operation. Built and operated by the Japan Aerospace Exploration Agency, in cooperation with Japan's Ministry of the Environment and National Institute for Environmental Studies, the craft will be succeeded this year by Ibuki 3.

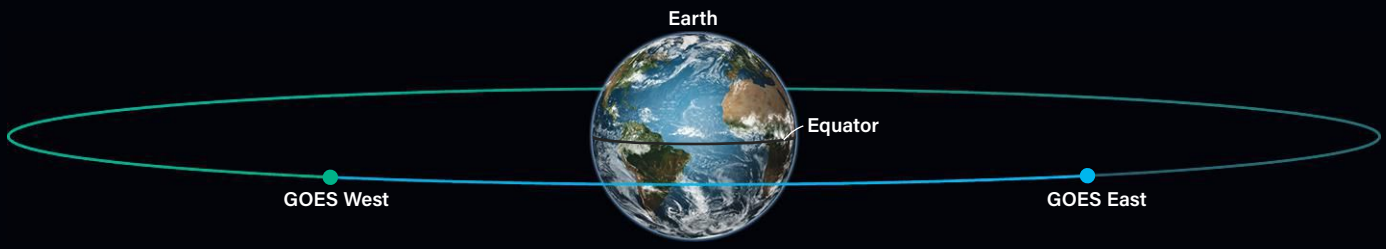
Ibuki's mission was in response to the 1997 Kyoto Protocol that directed nations to reduce their carbon emissions. But monitoring those emissions from the ground is patchwork and incomplete. Ibuki and its successors are able to map carbon dioxide and methane over nearly the entire surface of the planet every three days, allowing the world to track how and where greenhouse gases are increasing.





This chart shows the steadily increasing concentrations of carbon dioxide in the atmosphere (in parts per million). NOAA. IBUKI SATELLITE AT LEFT: JAXA

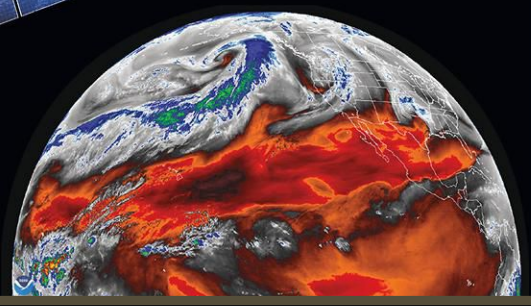
BOTH ORBIT DIAGAMS, TOP LEFT AND TOP RIGHT: *ASTRONOMY*: ROEN KELLY



GOES EAST AND WEST

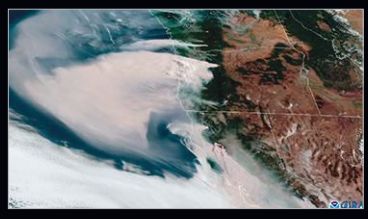
The Geostationary Operational Environmental Satellite (GOES) suite resides in a "parked" orbit 22,236 miles (35,785 kilometers) above Earth's equator and rotates with the planet, allowing its satellites lock their eyes on their chosen patch. GOES-R is the latest, most advanced version of the fleet, and comprises two satellites, dubbed East and West, each pointed at a spot near North America, where they keep tabs on the land, air, and sea within their domain. Another two satellites hang out in nearby orbit for backup, swapping into orbital place if either flagship breaks down.

Another joint NASA/NOAA program, GOES (in some version or another) has been watching Earth from space since 1965. The first GOES-R satellite launched in 2016, and the suite is NASA and NOAA's current best geostationary eyes for weather and climate covering the Western Hemisphere. Their instrument array covers multiband imaging and lightning mapping, and includes a range of solar radiation and space weather sensors, and more. This allows them to monitor everything from weather to wildfires, predict severe weather like tornadoes, and even aid in search and rescue missions by relaying transponder signals. Whether you need to launch a rescue or plan a picnic, GOES East and West have you covered — at least in the U.S.

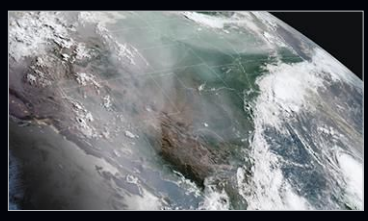


BELOW: An atmospheric river flows across the Northern Pacific Ocean in this GOES-West satellite image. CIRA/NOAA. GOES-R SATELLITE AT LEFT: NASA

The GOES-12 weather satellite captured this image of Hurricane Katrina on Aug. 28, 2005. NOAA



The GOES-17 satellite monitored extreme wildfire activity on the West Coast of the U.S. on Sept. 8, 2020. NOAA

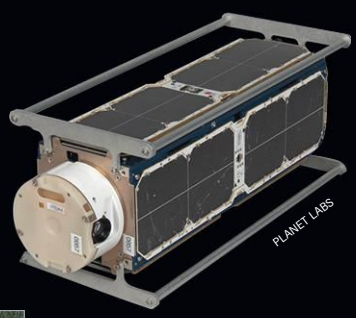


Hurricane Laura heads toward Texas and Louisiana in this GOES satellite image from Aug. 25, 2020. NOAA

PLANET

Planet is a private company that operates a fleet of some 200 satellites, providing the resulting data to a wide range of industries. For insurance, investment banking, transportation, forestry, civil projects, defense, agriculture, and more, there are many reasons why having an up-to-the-hour view of our changing planet might prove useful — and profitable.

In the absence of a space agency, Planet the company does the work of providing not just images, but also the data products that go with them. With this information, farmers can predict crop yields, governments and NGOs can track land use, and shipping companies can assess port usage. The possibilities are endless.



This pair of images shows an oil spill near Ancon, Peru, from Dec. 31, 2021 (left) to Jan. 18, 2022. PLANET LABS

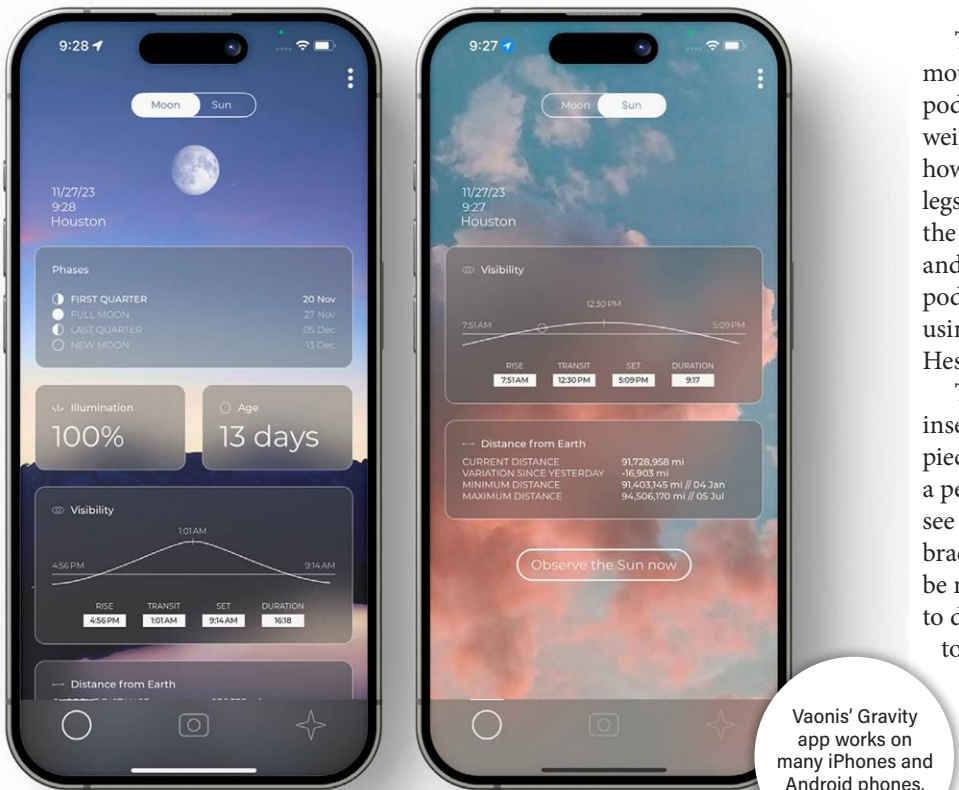
This view of the Disneyland parking lot in California was taken March 7, 2017. PLANET LABS

This image, taken Jan. 20, 2017, shows illegal mining occurring in Peru. PLANET LABS

Korey Haynes *is an accomplished science writer and former associate editor of* Astronomy.

A telescope for your smartphone

Vaonis' compact, easy-to-use Hestia will turbocharge your phone for astroimaging. BY RAYMOND SHUBINSKI



Vaonis' Gravity app works on many iPhones and Android phones. VAONIS

The new Hestia telescope by Vaonis is the third of the company's innovative instruments I have reviewed, and once again, I'm impressed.

Vaonis named their creation for the Greek goddess of the hearth and home, and released it after a successful 2023 Kickstarter campaign which raised $4.1 million in just a month. The Hestia is a small, portable device that uses your cellphone to capture images. Unlike its predecessors, which combined a telescope and camera into an all-in-one smartscope package, the Hestia contains only optics, relying on your cellphone and the Gravity app developed by Vaonis to do all the imaging.

I received the Hestia Ultimate Pack, which retails for $349. It came in a well-designed hard-shell case that contains the Hestia and accessories, including a solar filter, a basic Sun pointer, and a lightweight tripod.

The Hestia is an interesting example of telescope and optical construction. When I first unpacked the unit, I thought I was looking at a large iPad with a lens on one side.

The bottom of the Hestia has a screw mount that attaches to the provided tripod. This tripod is meant to be lightweight and portable; the tradeoff, however, is a lack of stability when the legs are fully extended. The mount on the Hestia accepts a ⅜" threaded screw and can't be used on many standard tripods whose screws are ¼"-20. If you're using an existing tripod to mount the Hestia, ensure that it has a ⅜" thread.

The top of the telescope has a large inset for your cellphone and an "eyepiece" for the phone's camera lens. I took a peek through the eyepiece and could see distant trees clearly. Two magnetic brackets secure the cellphone. These can be moved around on the inset to adjust to different phones. The brackets tended to slip a bit with my iPhone 13 Pro, which has a heavy steel case.

By keeping the cost of the Hestia low, Vaonis has provided the user with a unique observing experience. The Hestia has an interesting six-lens patented optical system. I would love to have seen the interior optics, but (wisely) the case is sealed. The objective lens is only 1.2 inches (30 millimeters) in diameter. The Hestia also incorporates a 25x zoom. The specifications do not indicate the focal length.

The Vaonis Gravity App helps to compensate for the lack of light-gathering power by using image-stacking software. The telescope provides reasonably good images of the Sun, Moon, and bright deep-sky objects. It also provides a nice bonus with great views of distant landscapes and wildlife. I live in a rural area and enjoyed looking for deer and

PRODUCT INFORMATION

Vaonis Hestia

Aperture: 1.2 inches
Zoom magnification: up to 25x
Dimensions: 9.5 by 6.5 by 2 inches (24.1 by 16.5 by 5.1 cm)
Required app: Gravity (free)
Price: Four pack options available, from $199 to $349
Contact: Explore Scientific
1010 S. 48th Street
Springdale, AR 72762
1-866-252-3811
www.explorescientific.com

examining the fall colors when I first used the Hestia.

The key to the scope is the Gravity App and your smartphone's optical system. The app is free in both Apple iOS and Android versions. You must download the app to take photographs with the Hestia. A QR code on the base of the telescope also needs to be scanned before you can pair the phone to the telescope.

Lining up the phone's camera lens with the Hestia's eyepiece is the next step after pairing. I had to try several times to successfully get my phone's three-lens system into the right position. I then had to move the magnetic brackets as close as possible to keep the phone from slipping away from the eyepiece. In fact, I had to remove the phone's case to secure the phone with the brackets. When I tilted the Hestia up in altitude the phone slipped a bit. I solved this problem with a long Velcro strap. As I mentioned, my iPhone 13 is heavy; this may not be an issue with other phones.

Not all cellphones will work with the Hestia. Vaonis provides a list of compatible phones on its website (https://support.vaonis.com/portal/en/kb/articles/which-smartphones-are-compatible-with-hestia). The company also says it will continue to update the list. Only the iPhone 13 and above are usable for deep-sky photography within the iPhone family. If you have an Android phone, make sure you look at the Vaonis website for compatibility before you buy a Hestia.

One of the most impressive aspects of Vaonis products is the support that comes with its telescopes. When I reviewed the Vespera smart telescope, I was impressed with the Singularity app that allowed the scope to find, track, capture, and process images. The Gravity app does the same thing for the Hestia, with the exception of tracking.

When you open Gravity, the first screen prompts you to choose between the Sun or Moon function. Using your phone's location, the app gives you detailed information about the Sun, Moon, and other celestial objects.

I first tried imaging the Sun. I placed the phone on the scope and lined up the camera lens to the eyepiece. By viewing some distant trees, I was able to check the focus. I screwed the Sun filter in place on the objective lens — the last thing you want to do is fry your phone's optics. The small Sun finder supplied with Hestia simply snaps into place on the side of the scope. This accessory is basic but works well.

One challenge I encountered was the glare on the phone's screen under the bright Sun. I put on a hat with a big brim which shielded my eyes. But once I found the Sun, it was easy to use the focus and choose the exposure time and ISO settings. Then, I just tapped the shutter icon and I had an image of the Sun. The software saved the image to the Hestia album on my phone.

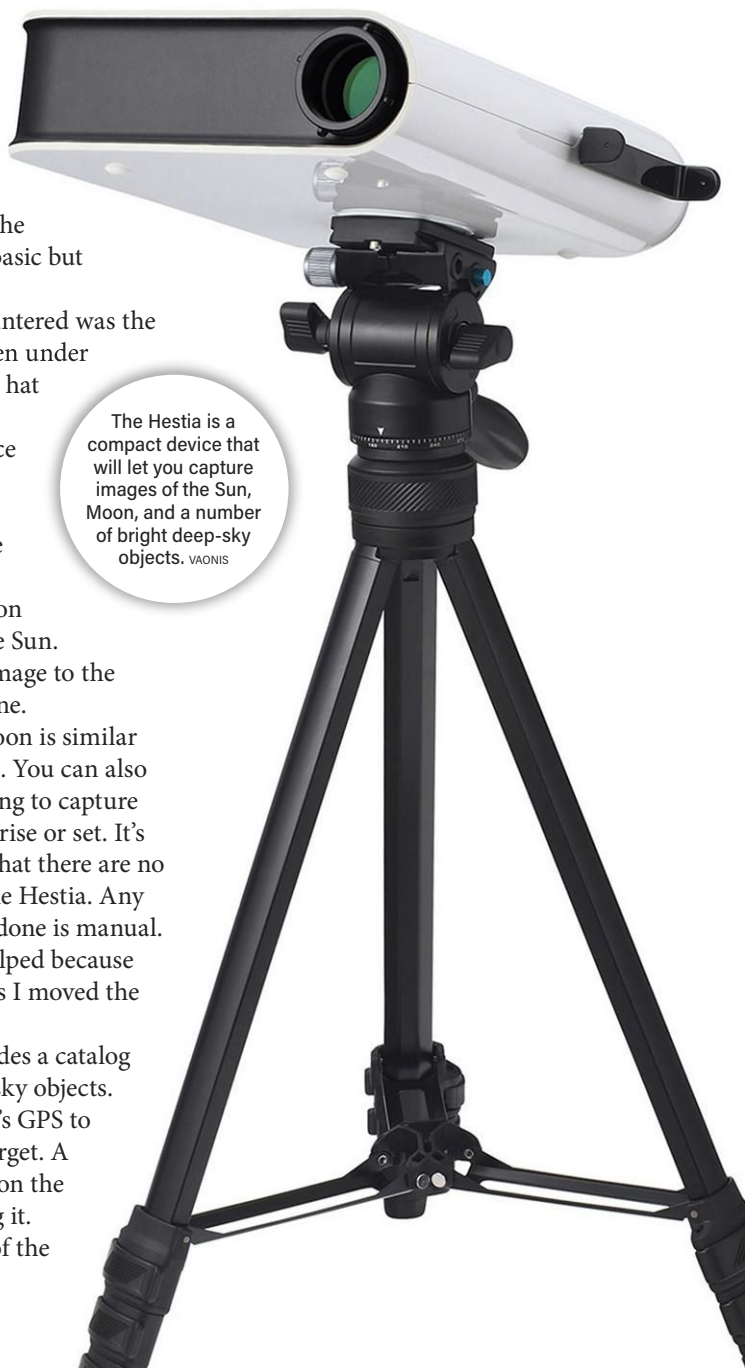
Photographing the Moon is similar and has the same options. You can also use the elapsed time setting to capture the Sun or Moon as they rise or set. It's important to remember that there are no electronics or drive for the Hestia. Any guiding that needs to be done is manual. Using a heavier tripod helped because there was less vibration as I moved the Hestia into position.

The Gravity app includes a catalog of bright stars and deep-sky objects. The app uses your phone's GPS to help guide you to your target. A green circle that appears on the phone helps with locating it.

For a planned image of the Orion Nebula (M42) when the Moon was up, I had problems with moonlight washing out details. Obviously, you need a nice dark sky to capture a good image. If you live in a light-polluted urban area, you may struggle with this process.

The Hestia is a great companion to your other telescopes, but I don't think it should be considered a stand-alone scope. Vaonis is an innovator in capturing the sky. Its Hestia is an economical way to start your journey creating images of lasting celestial memories.

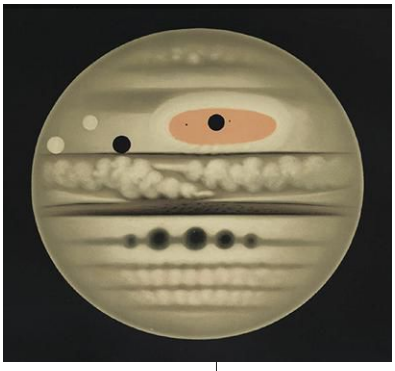
Raymond Shubinski *is a contributing editor of* Astronomy *and a lover of fine equipment who observes from his home in St. Joseph, Michigan.*

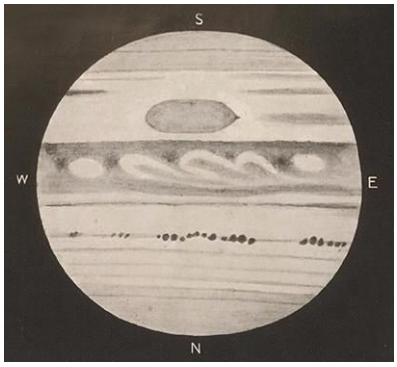


The Hestia is a compact device that will let you capture images of the Sun, Moon, and a number of bright deep-sky objects. VAONIS

Scar gazing

Impacts that leave visible marks on Jupiter are impressive — and rare — sights.





LEFT: Étienne Léopold Trouvelot drew Jupiter on Nov. 1, 1880, recording five large dark spots in the planet's North Temperate Belt (NTB). The spots have likely been erroneously enlarged in this reproduction. THE TROUVELOT ASTRONOMICAL DRAWING MANUAL (1882)

RIGHT: William F. Denning's Nov. 29, 1880, rendering of Jupiter shows how the "train" of small dark spots in the NTB evolved over time. SPLENDOUR OF THE HEAVENS, VOL. 1 (1923)

BY STEPHEN JAMES O'MEARA
Stephen is a globe-trotting observer who is always looking for the next great celestial event.

Lucky is the word I'd use for any telescopic observers who got to see one of the most stunning spectacles in nature when Comet Shoemaker-Levy 9 impacted Jupiter in July 1994. The collision left inky scars in the planet's atmosphere that persisted for months, with the largest welts visible in even the smallest of telescopes.

While at the time, witnessing an impact on another world seemed like a once-in-a-lifetime event, amateur astronomers and space scientists alike have continued to record other, albeit much smaller, impacts on Jupiter. About a dozen such events are known to date; undoubtedly that number will continue to rise.

In a 2018 *Astronomy & Astrophysics* paper titled "Small impacts on the giant planet Jupiter," Ricardo Hueso and colleagues estimated that small objects about 16 to 65 feet (5 to 20 meters) or larger should impact Jupiter and be observable from Earth once every 0.4 to 2.6 years. Most of these events have been captured as flashes without any discernible scarring — but larger events have occurred.

The large spots evolved into a long train of tiny spots.

Most notable was the July 19, 2009, dark impact scar discovered by Australian amateur astronomer Anthony Wesley. In images taken with his 14.5-inch reflector, the impactor (approximately 650 to 1,600 feet [200 to 490 m] in diameter) left a 5,000-mile-long (8,000 kilometers) dark scar in Jupiter's southern hemisphere.

In April 2024, Pawel Drozdzal, a Ph.D. student at Adam Mickiewicz University in Poland, alerted me to a paper published Feb. 1, 1997, in *Publications of the Astronomical Society of Japan*. In "Discovery of a possible impact spot on Jupiter recorded in 1690," lead author Isshi Tabe and colleagues reported their discovery of a dark spot drawn by Italian astronomer Giovanni Domenico Cassini in December 1690. They stated that the spot was similar to those produced by Comet D/Shoemaker-Levy 9's impact. Over a period of 18 days, Cassini observed and sketched this spot as it was stretched out by Jupiter's zonal winds into a series of wispy trails. Taking this series of drawings as circumstantial evidence — and using a simple simulation to confirm their suspicions — the authors concluded that the spot was "possibly produced by the impact of a single astronomical object around 1690 December 5."

Another eyebrow-raising Jupiter drawing was created on Nov. 1, 1880, by French astronomical artist Étienne Léopold Trouvelot, recording five large black spots on the planet's North Temperate Belt (NTB). He described the view in his 1882 book *The Trouvelot Astronomical Drawing Manual*, noting that in October 1880, a relatively calm four-year period on Jupiter ended "when considerable commotion occurred on the northern hemisphere." He also stated that when the spots first appeared, they "had some resemblance to Sun-spots without a penumbra, with bright markings around them, resembling faculae. These round spots subsequently enlarged considerably, until they united along the entire line, encircling the planet, and finally forming a narrow pink belt…"

In his classic 1958 work *The Planet Jupiter*, British astronomer Bertrand Peek wrote that this occurrence was the first time in recorded history that an outbreak of dark spots had been seen at the south edge of the NTB. The spots also displayed the shortest rotation periods that had ever been observed on Jupiter. Planetary scientists now know this region has the fastest zonal jet on Jupiter.

The renowned British observer William F. Denning also observed the NTB dark spots, first recording them on Oct. 23, 1880. By the end of October and early November, he tried to identify them at succeeding transits across the planet's central meridian but "found such considerable changes in their appearance and distribution that only the two principal spots could be followed," he reported in *The Observatory*. Indeed, compared to the five substantially large spots that Trouvelot drew, a later drawing by Denning on Nov. 29, 1880, shows how the spots had evolved into a long train of tiny spots.

While these statements are remarkably reminiscent of the SL-9 impact scars, transforming into a smoky red band as they dispersed, scientists don't have any direct evidence of an impactor. One could postulate that impacting objects may have triggered the creation of this disturbance, as observers had never seen dark spots at that location on the planet before, but there is no evidence.

I hope you continue to observe Jupiter, as one never knows when a comet or asteroid will strike. As always, send thoughts to sjomeara31@gmail.com.

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara**

the space store®

Explore the Universe

The Space Store offers an extensive selection of space mission patches, rocket and airplane models, meteorites, toys, books, and unique items from NASA, SpaceX, Boeing, and the U.S. Space Force.

Come and check out the largest retailer of NASA and space-themed collectibles, apparel, and gifts, serving enthusiasts of all ages!

Shop now at: TheSpaceStore.com/Shop

connecting you to the cosmos

Get thee to a star party!

'Tis the season.

The author observes through her 16-inch Discovery telescope at the 2024 Rocky Mountain Star Stare.
MOLLY WAKELING

BY MOLLY WAKELING
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

Time under dark skies is precious, and for a lot of us, getting out to those sites can be tough. When we do, often we end up observing alone, or with a few intrepid others at an astronomy club observing session. And sometimes that solitude is what we're looking for: just you and the sky.

But there's also real joy in sharing the telescope with others, whether they are experienced or rookies, and it's easier to stay up all night when you're with an enthusiastic crowd. There are many organized events across the country and around the world that bring people together under dark skies for a week or a weekend of observing. These events are called star parties.

Part outdoor astronomy convention, part summer camp for grown-ups.

I often describe star parties to my friends and co-workers as "part outdoor astronomy convention, part summer camp for grown-ups." (Although kids are welcome at star parties too!) All the star parties I know of involve camping to some degree. Many people bring their vans, campers, trailers, and RVs, although tent and car camping is also common. The Texas Star Party has cabins with bunks and hotel rooms. Others are camping only, such as Cherry Springs in Pennsylvania and Okie-Tex in Oklahoma. Camping is part of the fun for me — nights away from home in my cozy trailer are rejuvenating. But if you're looking for more of a "glamping" experience, the Nightfall Star Party in southern California is at a desert resort with hotel rooms, swimming pools, and a restaurant on-site. Some have catering for an extra fee, while others have food trucks; it's also fun to grill some steaks or have a nice cold sandwich out of the cooler. I brought a backpacking stove to the Hidden Hollow Star Party in Ohio, my first star party back in 2016, where I cooked grits, eggs, and bacon in the shadow of the dome that houses Big Blue, the club's giant 36-inch reflector.

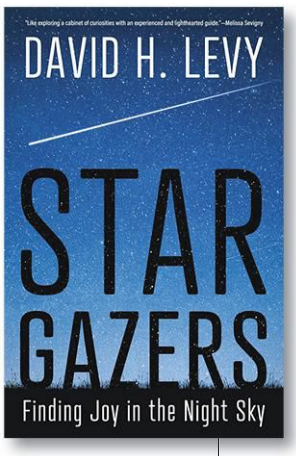
The heart of every star party is staying up late observing with friends new and old, hunting down targets that are tough to get from home and lingering on your favorite objects. Nearly every star-partygoer I've met has been happy to share their telescope view, which is a real treat when someone brings a big juicy Dob! I got to see the Whirlpool Galaxy (M51) through a 36-inch at the Texas Star Party one year, and it was breathtaking. One of my favorite things to do at a star party is to wander the main observing field. Especially at large events like the Texas Star Party, the air is electric with the excitement of observing under dark skies. I once got to see Omega Centauri, a massive Southern Hemisphere globular cluster that stands just 12° above the southern hills around Fort Davis, Texas, through 6-inch binoculars!

Star parties aren't only alive at night, however. Daytime activities can include presentations and workshops from amateur astronomers, scientists from NASA and the Green Bank Radio Observatory, and the occasional astronaut — Don Pettit gave a great talk at the 2017 Texas Star Party on "messing around" with microgravity experiments onboard the ISS that turned into scientific research. Because star parties are frequently in the middle of nowhere, there is usually a range of outdoor activities to participate in, such as hiking and birdwatching. (There's a large overlap between amateur astronomers and birders.) There is also, of course, plenty of socializing; I often sit in the main gathering building or tent and chat with people while I work on processing images on my laptop.

I spend most of my vacation days at star parties, socializing with other amateur astronomers and astroimagers from all over and soaking up the starlight against a black sky. There's nothing quite like gazing up at a broad, gauzy Milky Way, catching a shooting star every few hours, and enjoying beverages and conversation with other stargazers in between admiring our favorite clusters, galaxies, and nebulae through high-quality telescopes.

So what are you waiting for? Find a star party near you and remember why you fell in love with astronomy in the first place: https://www.go-astronomy.com/star-parties.htm. See you there!

BROWSE THE "OBSERVING BASICS" ARCHIVE AT
www.Astronomy.com/author/molly-wakeling



Sky watchers

The University of Arizona Press
Tucson, AZ

Star Gazers: Finding Joy in the Night Sky, by prolific astronomy writer David H. Levy, is a collection of personal essays celebrating amateur and professional astronomy. Bringing together his decades of sky-watching experience, this 172-page book gives readers insight into Levy's thoughts on James Webb Space Telescope, aurorae, and more.

$19.95 paperback, $19.99 ebook
orders@press.uchicago.edu
https://uapress.arizona.edu

Attention, manufacturers: To submit a product for this page, email **products@astronomy.com**.

Budget-friendly

Explore Scientific
Springdale, AR

The Explore One STAR70APP Refractor Telescope is a low-cost deep-sky and lunar scope that is good for beginners. Using the ARTelescope App, users can locate constellations, nebulae, and more. It comes with an adapter for attaching your phone to the eyepiece, as well as 26.9x and 72x eyepieces. The scope is operated by a manual, pan-handle mount.

$139.99
service@explorescientific.com
www.explorescientific.com

Field reduction

Apertura
Qionglin, Taiwan

The 0.75x Reducer is available for the Askar 75Q telescope, allowing you to widen your field of view and incorporate more light into the scope. With the ability to pull in one-and-a-half times more light than similar products, it is designed to reduce the focal length to 303 mm. It also includes five internal lenses.

$229.95
(800) 266-9590
www.highpointscientific.com

INDEX *of* ADVERTISERS

AP Gregorz Poplawski/Arch Paths 2
Bob's Knobs 53
Celestron 60
Comec snc di Mariotti G&C 11
Mason Capital Partners 11
Metamorphosis Jewelry Design 11
Northeast Astronomy Forum 6, 11
Oberwerk 11
Parks Canada / Goverment of Canada .. 59
QHYCCD 5
Rainbow Symphony 53
Scope Buggy 5
Subscribe and Save 59
TheSpaceStore.com 51

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

Want more *Astronomy?*

Get your FREE weekly *Astronomy* newsletter delivered to your inbox!

Astronomy

Go to **Astronomy.com/magazine/newsletter** for more info.

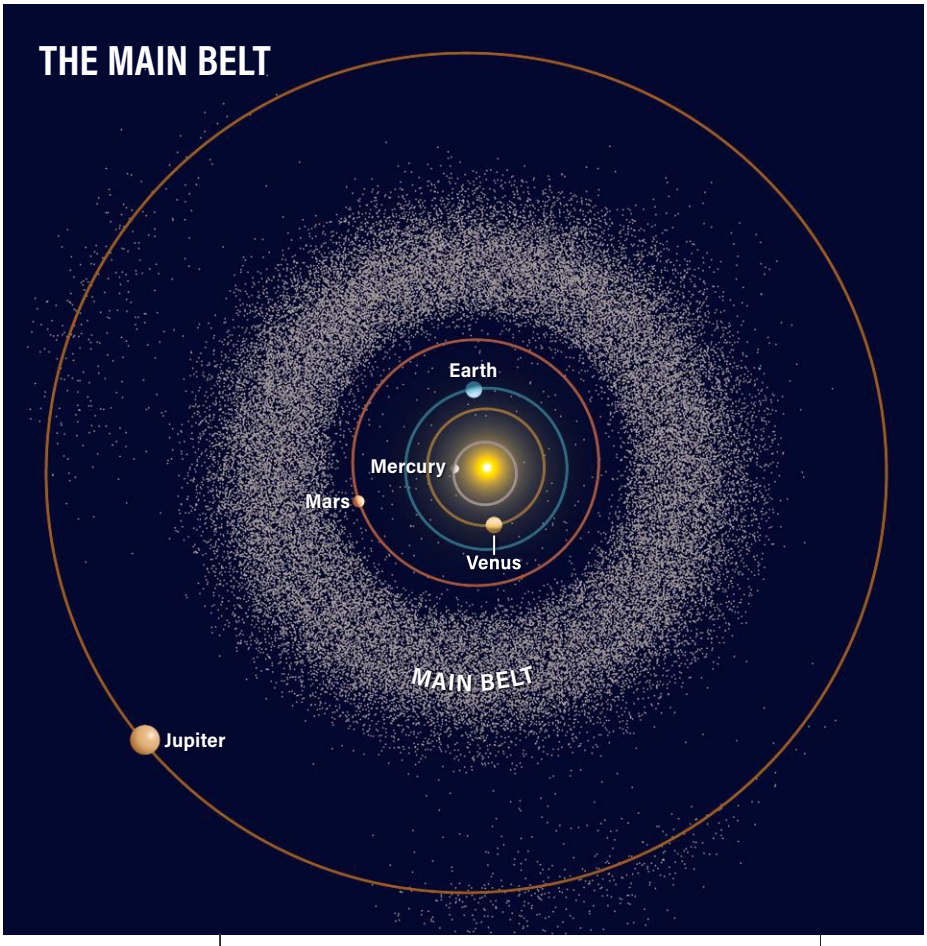
Bob's Knobs™
COLLIMATION THUMBSCREWS
www.bobsknobs.com

ECLIPSE SHADES™
Safe Solar Viewers
CE Certified
SAFE FOR DIRECT SOLAR VIEWING
Rainbow Symphony, Inc.
818-708-8400 • Fax 818-708-8470
www.rainbowsymphony.com

Explore the universe!
Subscribe to *Astronomy* magazine today!
Visit Astronomy.com

YOUR AD HERE
Call 608-435-6220
for advertising information

MARKETPLACE



The majority of known asteroids orbit in the main belt between Mars and Jupiter. It is unlikely that the many bodies here were ever part of a single planet. This illustration shows the positions of the planets and all numbered asteroids on Jan. 1, 2018.
ASTRONOMY: ROEN KELLY, AFTER P. CHODAS (NASA/JPL)

A lost planet?

Q | IS THERE EVIDENCE OF A PLANET EVER EXISTING BETWEEN MARS AND JUPITER?

Mark
Smithtown, New York

A | This splendid question gives us an opportunity to distinguish between what we know and what we believe might be true.

First, we know that myriad small bodies orbit the Sun between Mars and Jupiter. These objects are the asteroids that comprise the main belt. Astronomers estimate that 1.1 million to 1.9 million asteroids with diameters equal to or exceeding 0.6 mile (1 kilometer) are located within this region, with millions more smaller asteroids likely lurking as well. That's quite a substantial number of rocks. It would seem as though those asteroids could form quite a planet if put together. But, surprisingly, if all the main-belt bodies were to coalesce, the resultant world's mass would only be 4 percent that of the Moon. (To put that value into perspective, the Moon's mass is only 1.2 percent that of Earth.) And half of that mass is concentrated in the four largest bodies: Ceres, Vesta, Pallas, and Hygiea.

The notion that these fragments could have come from a planet that was somehow reduced to fragments arose out of the 1801 discovery of Ceres by Giuseppe Piazzi and the 1802 discovery of Pallas by Heinrich Olbers. Olbers became convinced that these two bodies were pieces of a larger world that had once existed, and the subsequent discoveries of Juno (1804) and Vesta (1807) lent credence to this belief. The hypothetical doomed planet was soon thereafter given the name Phaëthon (or Phaeton), after the ill-fated son of the Greek Sun god Helios, who tried to drive his father's chariot for one day and perished as a result. This idea evolved into what was known in the 20th century as the disruption theory, which stated that a planet between Mars and Jupiter had been destroyed by some unknown means, perhaps tidal interactions with Jupiter or a collision with another body.

Could the main belt have formed from the remains of a destroyed planet? How could we know one way or the other? One important clue practically fell into our laps. Iron meteorites on Earth that are known to have come from the main belt have been determined not to have all originated from the same body. The patterns within these meteorites are quite different from one another; fragments of a single world would show more similarities. The analysis of these meteorites, combined with the comparative dearth of material within the main belt, leads us to believe that no planet ever existed between the orbits of Mars and Jupiter after all. The asteroids are likely just remnants from the early days of solar system formation.

Moreover, we shouldn't expect any planet to form within the main belt in the future, since Jupiter's considerable gravitational influence keeps the asteroids in a perpetual spin cycle, preventing them from gathering together to make a new world.

We can't assert that no planet ever existed between Mars and Jupiter. We can, however, say that it is highly unlikely one ever did.

Edward Herrick-Gleason
Staff Member, Southworth Planetarium, University of Southern Maine, Portland, Maine

Q | BEFORE EINSTEIN, SPECIAL RELATIVITY, AND $E = mc^2$, WHAT WAS THE PREVAILING THEORY ON THE SUN'S SEEMINGLY ETERNAL ENERGY?

William Fields
Dayton, Ohio

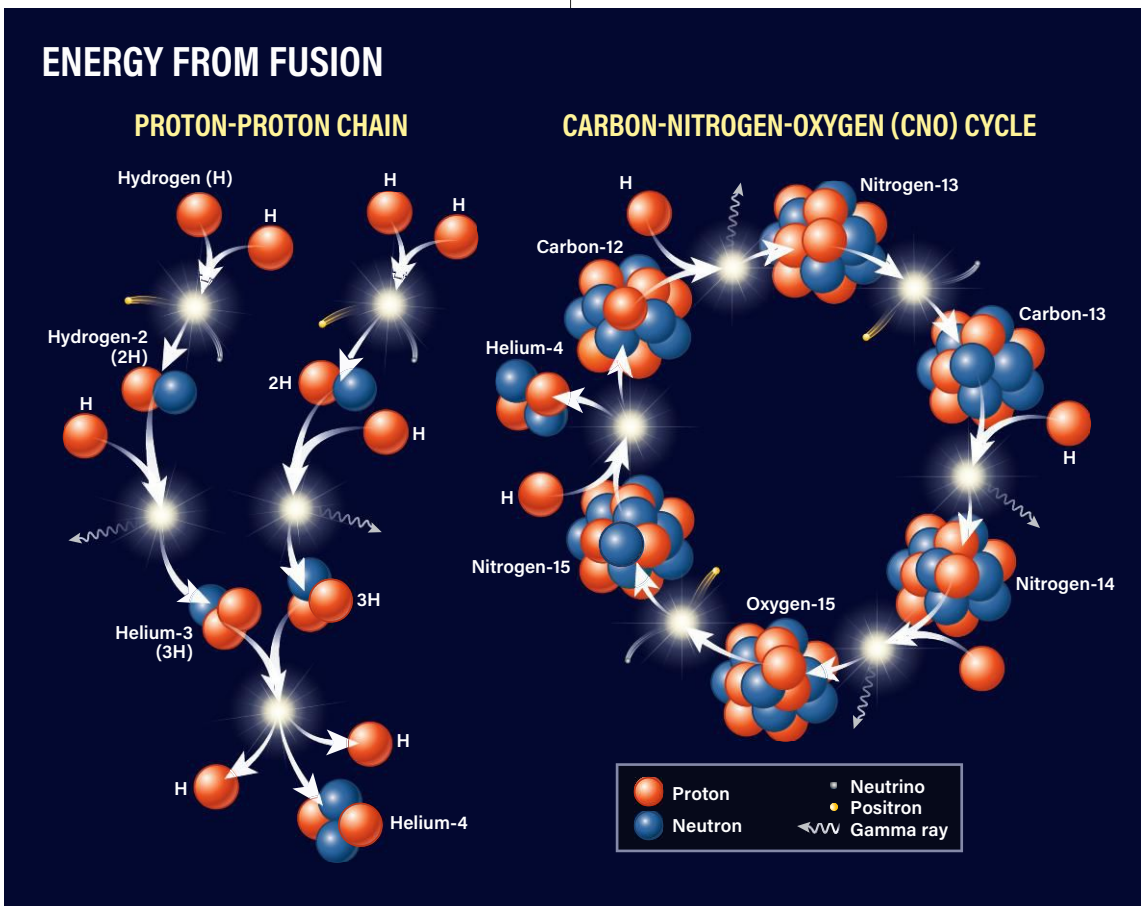
A | The question of what energy source powers the Sun has been around for literally centuries. During the 1800s, some thought that a constant shower of meteors onto the Sun might do the trick. Others considered (and rejected) any number of chemical combustion processes.

Independently, William Thompson (also known as Lord Kelvin) and Herman von Helmholtz came up with the idea of solar contraction in the mid-1800s. This is usually called the Kelvin-Helmholtz contraction theory. It proposed that the Sun is contracting slowly, and this contraction heats the star by converting gravitational potential energy into kinetic-thermal energy. Both performed the requisite calculation and came up with a solar lifetime between 20 million and 500 million years. However, this was in many cases much too short to be compatible with geologic evidence for the age and evolution of mountains on Earth.

IT IS HIGHLY UNLIKELY THAT A PLANET EVER EXISTED BETWEEN MARS AND JUPITER.

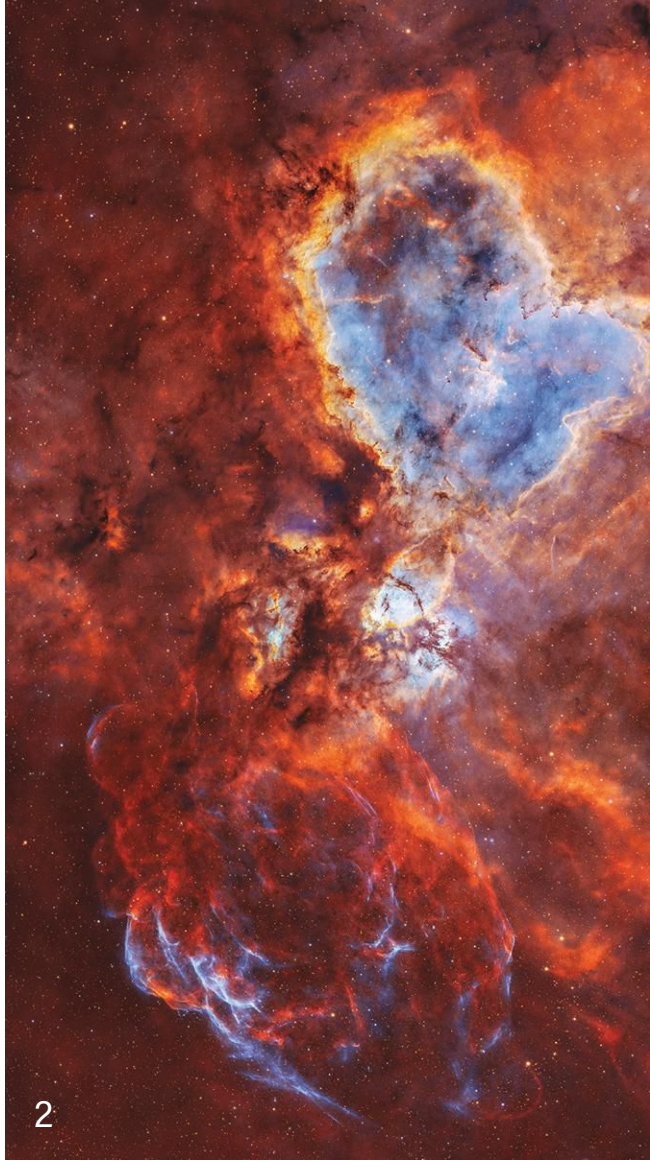
Nevertheless, it was our best guess as to the origin of solar heating, and it held sway until the dawn of the nuclear age. In the 1920s, Sir Arthur Stanley Eddington developed the concept of proton-proton fusion, which converts hydrogen into helium. Then, Hans Bethe in 1938 worked out the details of the carbon-nitrogen-oxygen (or CNO) nuclear fusion cycle, which also fuses hydrogen into helium. Both of these processes cause mass to be "lost." Finally, Einstein's iconic formula $E = mc^2$ was indeed the mechanism that explained the conversion of the liberated mass into nuclear energy in the quantities needed to power the Sun and stabilize it against gravitational contraction, as we know to be the case today.

Sten Odenwald
Senior Outreach Coordinator, NASA HEAT Program, Kensington, Maryland



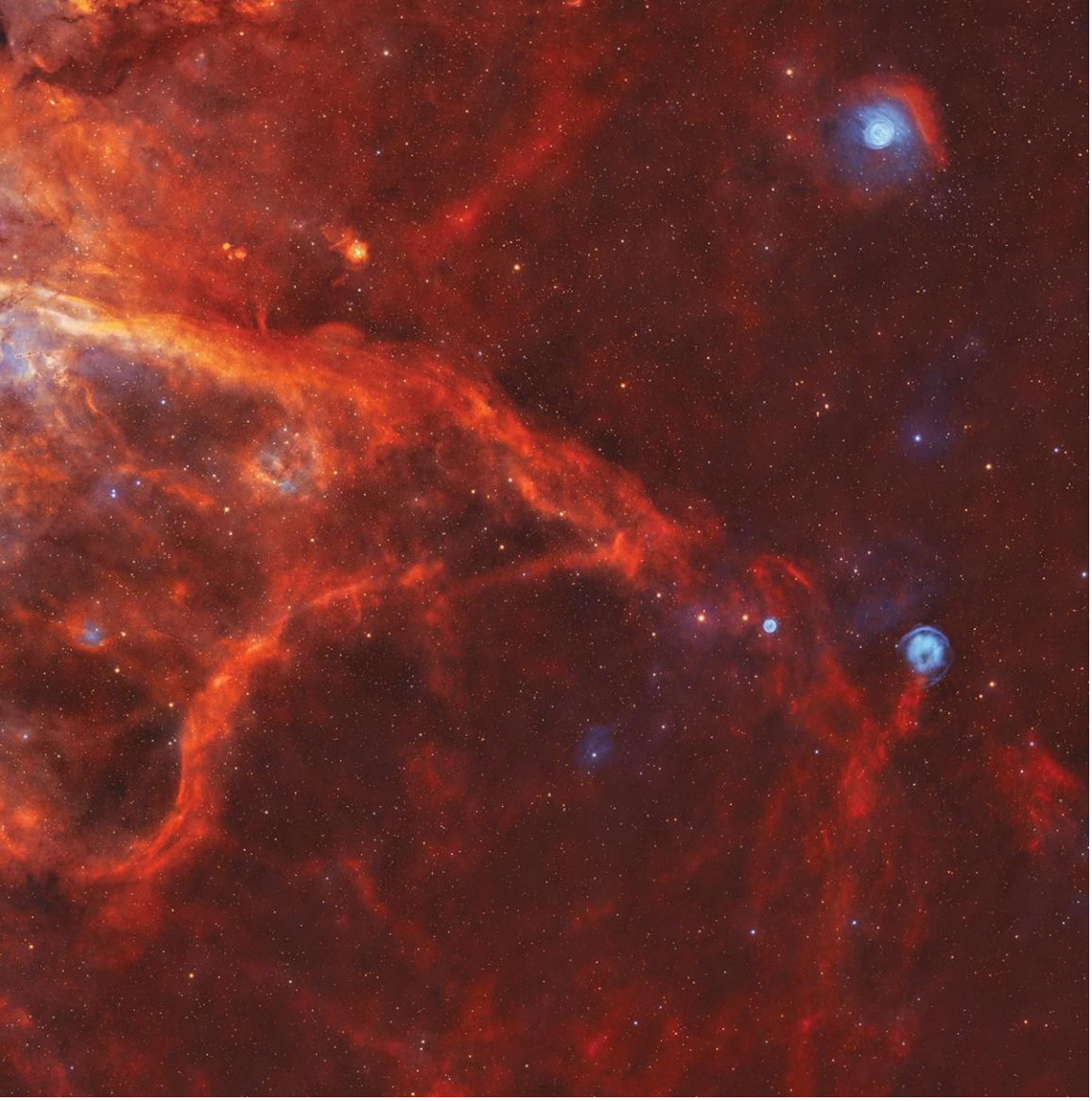
The proton-proton chain (left) is the chief fusion mechanism by which the Sun produces energy. During this reaction, four protons (hydrogen nuclei) combine to create one atom of helium-4, the most common form of helium. In the CNO cycle (right), carbon-12 goes through several conversions, becoming various isotopes of nitrogen, carbon, and oxygen before returning to carbon-12. The last step produces helium-4. In both processes some small amount of mass is "lost," transformed into energy. *ASTRONOMY:* ROEN KELLY, AFTER BORB/ WIKIMEDIA COMMONS

1



2

3



4

1. STAR GRAZING
A windswept tree lies beneath the Milky Way at the edge of a dew pond atop Ditchling Beacon in Sussex, U.K. The photographer used a Canon DSLR and 35mm f/1.4 lens to image the sky with nine 60-second frames at ISO 800, plus three Hα frames of 150 seconds each at ISO 4000 to capture emission in the Milky Way. The foreground is a single 100-second exposure with a 14mm f/2.8 lens at ISO 800. ***• Marco Wong***

2. DISSECTING THE HEART
The Heart Nebula (IC 1805) in Cassiopeia lies exposed in this 405-hour Hubble-palette image taken with a 1.6-inch scope. Wider than most images of the Heart, it contains a grand tapestry of stellar life and death. While the heart of the Heart bursts with star formation, several dying stars are visible at right as planetary nebulae, with winds of ionized oxygen glowing in blue. At lower left lie the shells of a supernova remnant. ***• Drew Evans/Jeffery Horne***

3. LOOMING LARGE
Physically, Mars is nearly twice the diameter of the Moon. But on Jan. 13, it lay 250 times farther away as it was occulted, making for an interesting exercise in scale. The photographer captured this moment before ingress with a Sony mirrorless camera and 600mm lens with a 2x teleconverter, taking a 1/100-second exposure at f/14 and ISO 200. ***• Chirag Upreti***

4. EQUESTRIAN ARTISTRY
This previously unnoticed reflection nebula lies in Perseus amid a bright mid-infrared region surveyed by the Infrared Astronomical Satellite (IRAS). The imager took over 33.4 hours of exposure in LRGB filters with a 12-inch scope, revealing the nebula seen here. He has named it the Dancing Horse Nebula — not be confused with the Prancing Horse dark nebula near the galactic core. ***• Michael Telesco***

SEND YOUR IMAGES TO: readergallery@astronomy.com.
Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures.

BIG, BRIGHT, AND BEAUTIFUL

The Southern Pinwheel Galaxy (M83) in Hydra checks almost every box an amateur astronomer could desire. This stunning barred spiral spans a hefty 14' and, at magnitude 7.5, ranks among the sky's 10 brightest galaxies. Its only drawback is location — at a declination of –30°, it lies farther south than any other galaxy in Messier's catalog. M83 stands out for its striking spiral arms, which feature an abundance of glittering blue star clusters and the pinkish emission nebulae that give birth to them. Astronomers think the galaxy's high rate of star formation stems from an encounter with another galaxy. Some researchers suspect the nearby dwarf irregular NGC 5253 is the cause, while others point to a possible second nucleus in M83's core as the remnant of the offending galaxy. CTIO/NOIRLAB/DOE/NSF/AURA

Wood Buffalo National Park

Parc national Wood Buffalo

Light Up the Night!

Escape to the **world's largest Dark Sky Preserve**
Wood Buffalo National Park

Each August, Wood Buffalo National Park comes alive with the **Dark in the Park** festival, a celebration of the breathtaking skies above. The park has over 240 nights of aurora borealis activity each year, making this place a must see for stargazers, nature lovers, and those in search of something truly extraordinary.

August 2025
In Wood Buffalo National Park
Fort Smith, Northwest Territories, Canada

Ready to Light Up the Night?
For more information, visit:
parks.canada.ca/woodbuffalo

Illuminez la nuit!

Évadez-vous dans la plus **grande réserve de ciel étoilé au monde**
Parc national Wood Buffalo

Tous les ans, en août, le parc national Wood Buffalo accueille le festival **Le parc, la nuit** qui célèbre le ciel époustouflant. Le parc est réputé pour plus de 240 nuits d'aurores boréales chaque année, ce qui fait de cet endroit un incontournable pour les observateurs d'étoiles, les amoureux de la nature et ceux qui recherchent l'extraordinaire.

Août 2025
Dans le parc national Wood Buffalo
Fort Smith, Territoires du Nord-Ouest, Canada

Vous êtes prêt à illuminer la nuit?
Pour plus d'informations, visitez :
parcs.canada.ca/woodbuffalo

Parks Canada Parcs Canada

Canada

CELESTRON®

STEP UP TO
PEAK PRECISION + PERFORMANCE

StarSense® AUTOGUIDER

Blue Horsehead Nebula ● AVX 8" RASA and SSAG ● C.Hendren

Celestron engineers are obsessed with squeezing every last drop of potential from your gear. StarSense Autoguider is their all-in-one solution that makes observing and astroimaging easier—and way more fun—than ever before.

Automatic Alignment: Be ready to observe in minutes
Let your telescope align itself to the night sky in about three minutes with no user input. With patented StarSense technology, StarSense Autoguider detects star patterns overhead and matches them to its internal database to automatically orient the telescope.

Precise GoTo: Supercharge your pointing accuracy
You can count on your Celestron mount to place any object in the field of view of a low-powered eyepiece. But when you add StarSense Autoguider, you boost that power. Objects appear in the center of even high-powered eyepieces and small imaging sensors.

Autoguiding: Create your celestial masterpiece
After it centers your target with bullseye accuracy, StarSense Autoguider keeps it centered for as long as you're tracking. This one simple device delivers pinpoint stars in long-exposure astroimages—replacing a separate autoguiding camera, guidescope, and computer.

Assisted Polar Alignment: Dial in an accurate alignment with ease
You don't need a precise polar alignment to use StarSense Autoguider, but doing so provides the best performance possible. StarSense Autoguider walks you through an easy, automated process to get you there.

More about StarSense Autoguider
- Features a high-quality 4-element optical design with sharper optics than other mini-guidescopes, designed by famed optical designer Mark Ackermann
- Works with your hand control, a wired PC connection to CPWI software, or WiFi
- Includes an onboard computer and Sony IMX462LLR-C monochrome CMOS image sensor
- Compatible with most Celestron computerized mounts*

Get started today at **celestron.com/ssag**

*Visit our website for a full compatibility list.

PREMIER SELECT DEALERS

B&H Photo – 800.947.9970 – bhphotovideo.com
High Point Scientific – 800.266.9590 – highpointscientific.com
Astronomics – 800.422.7876 – astronomics.com
Woodland Hills – 888.427.8766 – telescopes.net
Adorama – 800.223.2500 – adorama.com
Focus Camera – 800.221.0828 – focuscamera.com
Agena Astro Products – 562.215.4473 – agenaastro.com
Mile High Astronomy - 877.279.5280 – milehighastro.com
Orange County Telescopes - 888-471-9991 – octelescope.com

June 2025
Venus at its morning best

The first evening of June finds **Mars** in the company of a lovely crescent Moon. The Red Planet reached opposition back in January and has faded considerably since then, glowing now at 1st magnitude.

Mars spends the month moving eastward against the backdrop of Leo the Lion. It shares a small patch of sky with Leo's brightest star, 1st-magnitude Regulus, in mid-June. The two meet on the 17th, when the planet passes less than 1° north of the star. Be sure to compare the ruddy color of Mars with Regulus' blue-white hue.

Alas, Mars now lies on the opposite side of the Sun from Earth and appears only 5" across when viewed through a telescope. Even large amateur instruments will struggle to show any surface details.

You might catch a glimpse of **Jupiter** low in the northwest during evening twilight in early June. On the 1st, it glows at magnitude –1.9 and lies about 5° high 45 minutes after sunset. It soon disappears in the twilight glow as it heads toward solar conjunction June 24.

As Jupiter exits the evening stage, **Mercury** makes a grand entrance. The innermost planet climbs a bit higher in the northwest with each passing day, and by June 30 stands 10° high an hour after sunset. It shines at magnitude 0.3 and appears obvious in the deepening twilight. Don't confuse Mercury with the similarly bright star Procyon, which lies 20° to the planet's left.

Point a telescope at Mercury and you'll see a half-lit disk that spans 7". Its phase will wane and its size will grow during the first half of July.

Once Mars sets, you'll have to wait a few hours for the other two naked-eye planets to appear. First up is **Saturn**, which rises around 2 A.M. local time in early June and some two hours earlier by month's end. The ringed planet shines at magnitude 1.0 among the faint background stars of southern Pisces the Fish.

If you've been watching Saturn through a telescope these past few months, you'll have noticed that the rings have started to open. In mid-June, they span 39" and tilt 3.4° to our line of sight. The narrow tilt means that the rings don't reflect as much light in our direction as they normally do, making the planet's satellites easier to see. In addition to 8th-magnitude Titan, which shows up through any instrument, keep an eye out for the trio of 10th-magnitude moons: Tethys, Dione, and Rhea.

The final planet to appear on these June nights is also the most dazzling: **Venus**. The brilliant planet rises between 3 A.M. and 4 A.M. all month. Shining brighter than magnitude –4.0 this month, Venus outshines every other celestial object except for the Sun and Moon. The planet moves eastward relative to the background stars during June. It starts the month in Pisces, briefly traverses a corner of Cetus, and then crosses Aries before entering Taurus at month's end.

Venus reaches greatest elongation June 1, when it lies 46° west of the Sun and stands 30° high in the northeast an hour before the Sun rises. At greatest elongation, the planet's disk appears 24" across and half-lit when viewed through a telescope. At the end of June, Venus spans 18" and shows a 63-percent-lit phase.

A nearly Full Moon occults the 1st-magnitude star Antares on June 10. Prime viewing locations include Australia and New Zealand. From Sydney, Antares disappears behind the Moon's western limb at 9h24m UT and reappears at the eastern limb at 10h40m UT. The corresponding times for Brisbane are a little earlier, at 9h16m UT and 10h30m UT.

The starry sky

As twilight fades these June evenings, the southern sky provides a magnificent tableau. Crux the Cross sits due south with the Pointers (Alpha [α] and Beta [β] Centauri) to its left. On the opposite side — to the west — lies a rich region in the vicinity of Eta (η) Carinae. Among these stars appears a character that Dutch-Flemish astronomer Petrus Plancius introduced more than 400 years ago. Alas, Polophylax, whose name means watcher or guardian of the pole, did not last long as a constellation.

Andrea Corsali was the first European to depict the Cross. He drew a crude map of this region in 1516 that showed it as it would appear from outside the imaginary celestial sphere, a common practice at the time. Although the stars are far from being in their exact positions, the Cross is easy to see and two bright stars to its right appear to be Alpha and Beta Cen.

Corsali drew a group of stars on the Cross' other side that does not correspond strongly with the actual stars in this area. If you think in more forgiving terms, however, Corsali simply may have portrayed some scattered stars in eastern Carina even less precisely than he did the Cross and the Pointers.

Plancius, relying on Corsali's drawing, appears to have interpreted these stars as having the shape of a standing person, Polophylax, and drew such a figure on his 1592 and 1594 maps. Interestingly, Plancius placed the Cross and Polophylax incorrectly — a long way from Centaurus and on the opposite side of the South Celestial Pole.

The end of the pole's guardian came a few years later, when Plancius had access to Pieter Dirkszoon Keyser's far better observations. I find this sad because Plancius made him look quaint, dressing him in a blue cloak.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. June 1
8 P.M. June 15
7 P.M. June 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

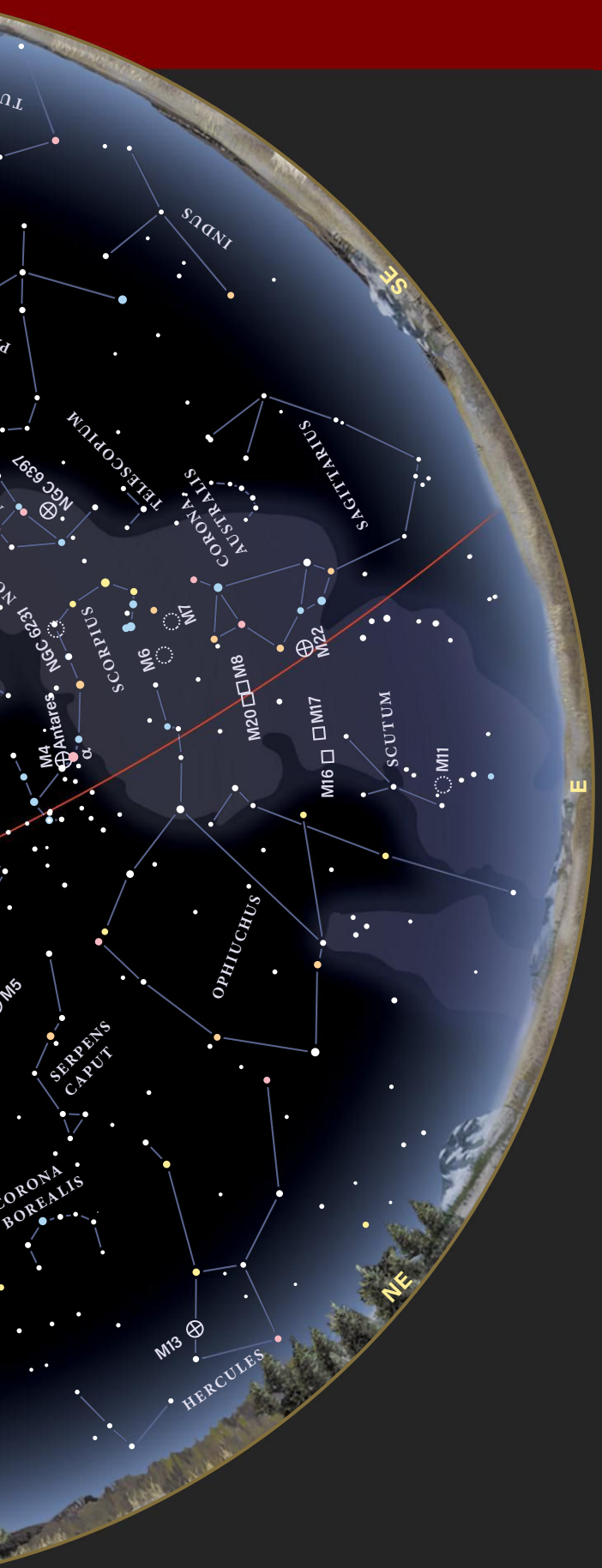
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



JUNE 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 Venus is at greatest western elongation (46°), 4h UT

The Moon passes 1.4° north of Mars, 10h UT

3 First Quarter Moon occurs at 3h41m UT

Asteroid Pallas is stationary, 21h UT

6 The Moon passes 0.5° south of Spica, 15h UT

7 The Moon is at apogee (405,553 kilometers from Earth), 10h44m UT

8 Mercury passes 2° north of Jupiter, 20h UT

10 The Moon passes 0.3° south of Antares, 11h UT

11 Full Moon occurs at 7h44m UT

14 The Moon passes 0.1° south of Pluto, 17h UT

17 Mars passes 0.8° north of Regulus, 4h UT

18 Asteroid Vesta is stationary, 19h UT

Last Quarter Moon occurs at 19h19m UT

19 The Moon passes 3° north of Saturn, 4h UT

The Moon passes 2° north of Neptune, 4h UT

21 Winter solstice occurs at 2h42m UT

22 The Moon passes 7° north of Venus, 9h UT

Mercury passes 5° south of Pollux, 20h UT

23 The Moon passes 5° north of Uranus, 4h UT

The Moon is at perigee (363,178 kilometers from Earth), 4h44m UT

24 Jupiter is in conjunction with the Sun, 15h UT

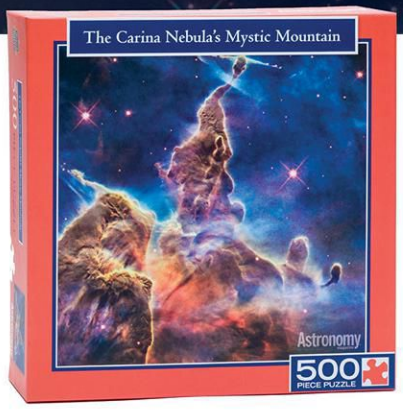
25 New Moon occurs at 10h32m UT

27 The Moon passes 3° north of Mercury, 6h UT

29 Saturn passes 1.0° south of Neptune, 8h UT

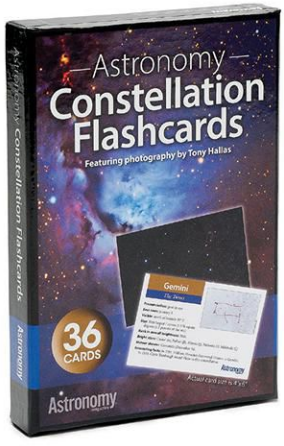
30 The Moon passes 0.2° north of Mars, 1h UT

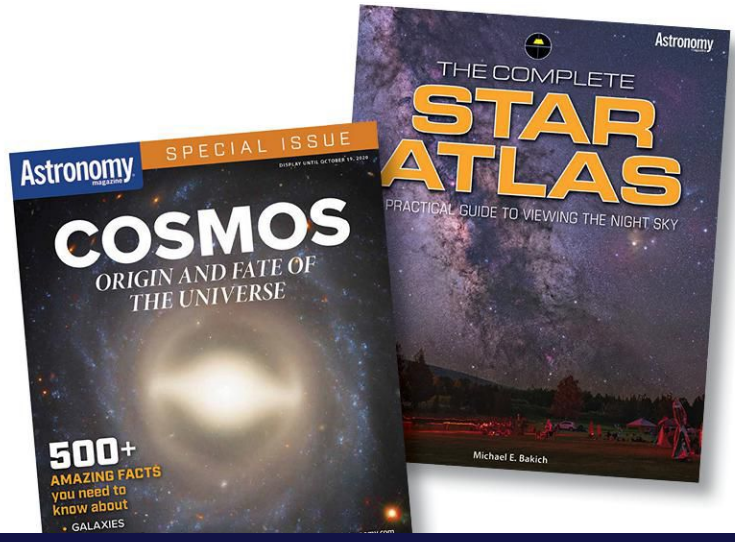
EXPLORE THE UNIVERSE



Visit TheSpaceStore.com today for high-quality astronomy products, many curated by the *Astronomy* magazine team.

- Custom-produced globes, as well as others from top manufacturers.
- Books and DVDs covering solar eclipses, observing guides, the cosmos and more.
- Magazines bringing you the latest astronomical discoveries and events.
- Collectible items to commemorate historic launches.
- Toys and games-have fun learning about astronomy!
- And much more!





space® STORE

Shop now at:
TheSpaceStore.com
Sales tax where applicable.

P39082